TRANSACTIONS OF THE

American Foundrymen's Association

Proceedings of the

Twenty-seventh Annual Meeting

CLEVELAND, OHIO

April 30 to May 3, 1923

VOLUME XXXI

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Edited by
ROBERT E. KENNEDY

Published by the American Foundrymen's Association
Chicago, Ill.
1924

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Summary of the Proceedings of the Twenty-seventh Annual Meeting

Cleveland, O., April 30 to May 3, 1923

The twenty-seventh annual convention, held at Cleveland from Saturday, April 28 to Thursday, May 3, was probably the most enthusiastic and well attended meeting ever held, both from the standpoint of interest in the equipment exhibits and the discussion of the papers at the technical sessions.

The plan of opening the exhibits on Saturday and closing the session on Thursday proved to be very popular and was commended by those who have been regular attendants at past meetings.

The technical sessions, 11 in all, brought out some of the most valuable papers ever presented at American Foundrymen's association meetings, and the valuable discussion indicated a great increase in the interest of all classes of foundrymen in scientific advancement of the industry. The question of molding sand was given greatest prominence because of the research information brought out by activities of the joint American Foundrymen's association and National Research Council Committee on Foundry Sand Research. Two sessions were devoted to this subject.

As at the twenty-sixth annual meeting, two joint sessions with the Institute of Metals division were held, one on brass and bronze foundry topics and one on aluminum alloy topics.

The two sessions on new developments in the foundry proved of great interest and those in attendance at these meeting voted to request the committee to make such meetings annual affairs. The increasing importance of the association committee work was shown by large numbers of technical committee reports presented; the thirteen reports presented being the largest number ever being given at one meeting. The committee on apprentice training had an entire session devoted to

this subject at which many short papers were read explaining methods used in different plants.

Joint Nonferrous Session

A. F. A. and Institute of Metals Division, A. I. M. E.

Monday, April 30, 2 p. m., assembly hall, Hollenden hotel. Jesse L. Jones, past president, Institute of Metals, in the chair. This session was devoted to aluminum and aluminum alloy subjects, and the following addresses were read and discussed:

"Linear Contraction and Shrinkage of Some Aluminum Alloys," by R. J. Anderson, bureau of mines, Pittsburgh.

"Density of Magnesium from 20 degrees Cent. to 780 degrees Cent.," by J. D. Edwards and C. S. Taylor, Aluminum Co. of America, New Kensington, Pa.

"Aluminum and Light Alloys," by R. de Fleury, France, Annual Exchange Paper of Association Technique de Fonderie.

"Casting Aluminum Radiator Shells," by W. A. Mills, Alloy Foundry and Machine Corp., New Rochelle, N. Y. Presented by title.

In the absence of the author the paper by R. de Fleury was read by G. H. Clamer, vice president of the American Foundrymen's association.

Steel Session

Monday, April 30, 2 p. m., ball room, Hollenden hotel.

C. S. Koch, past president, American Foundrymen's association, presided as chairman. Four papers, each illustrated with lantern slides, were presented and discussed. These papers were as follows:

"Production of Light Steel Castings for Ordnance Work," by Captain H. C. Minton, United States ordnance department, Watertown arsenal, Watertown, Mass.

"Heat Generation in Open-Hearth Practice," by A. D. Williams, Cleveland.

"Centrifugal Casting of Steel," by Harvey Young of McConway & Torley, Pittsburgh.

"Microscopic Examination of Foundry Sands," by H. W. Dietert, University of Illinois, Urbana, Ill.

Report of Committee on Specifications for Steel Castings.

Industrial Education

Tuesday, May 1, 9:30 a. m., the lounge, Hollenden hotel. Dr. Richard Moldenke, of Watchung, N. J., in the chair.

The following men presented written discussion on the subject of foundry training:

W. F. Simon, Apprentice Division, Industrial Commission of Wisconsin, Madison, Wis.

E. A. Parker, Springfield Aluminum Plate and Casting Co., Springfield, O.

C. M. Morrin, Apprentice Supervisor, Brown & Sharpe Mfg. Co., Providence, R. I.

A. B. Mays, University of Illinois, Urbana, Ill.

J. Roy Tanner, Pittsburgh Valve & Foundry Co., Pittsburgh.

John Grennan, University of Michigan, Ann Arbor, Mich.

L. W. Klein, Coxe Traveling Grate Co., Port Carbon, Pa.

H. A. Frommelt, Apprentice Supervisor, The Falk Corp., Milwaukee.

C. C. Hayward, Apprentice Supervisor, Bucyrus Co., South Milwaukee, Wis.

O. W. Potter, The University of Minnesota, Minneapolis, Minn.

F. W. Kirby, Deere & Co., East Moline, Ill.

In the absence of the author, chairman Moldenke read a discussion by A. L. Williston, of Wentworth Institute, Boston.

Joint Meeting, Nonferrous Foundry Practice, Tuesday, May 1, 9:30 *a. m., Assembly Hall, Hollenden Hotel*

G. H. Clamer, Vice President of the American Foundrymen's association, acted as chairman. The following papers presented in behalf of the American Foundrymen's association and Institute of Metals Division, American Institute of Mining and Metallurgical Engineers were read and discussed.

"Notes on the Proper Pouring and Melting of Brass and Bronze," by F. L. Wolf and W. Romanoff, Ohio Brass Co., Mansfield, O.

"Casting Bronze Tablets," by Jacob G. Kasjens,* Brass Foundry Co., Peoria, Ill.

"Contraction and Shrinkage of Nonferrous Alloys," by R. J. Anderson, Bureau of Mines, Pittsburgh, and E. G. Fahlman, National Smelting Co., Cleveland.

"Briquetting Brass Turnings," by F. L. Wolf, Ohio Brass Co., Mansfield, O.

"Effect of Heat Treatment on Release of Stress in Bronze Castings," by R. J. Anderson, Bureau of Mines, Pittsburgh, and C. L. Eldridge, Metropolitan Museum of Arts, New York City.

*Deceased

Cast Iron and the Electric Furnace

Tuesday, May 1, 9:30 *a. m., Ball Room, Hollenden Hotel*

L. L. Anthes, past president, American Foundrymen's Association, in the chair. The following papers were read and discussed.

"Gray Cast Iron from the Point of View of the Electric Furnace," by G. K. Elliott, The Lunkenheimer Co., Cincinnati.

"Electric Furnaces from the Manager's Viewpoint," by L. F. Barton, of Diebert, Bancroft & Ross, Ltd., New Orleans.

"Manufacture of Synthetic Foundry Iron," by C. E. Sims, C. E. Williams, and B. M. Larsen, Northwest Experiment Station, United States Bureau of Mines, Seattle Wash.

Report of Committee on Corrosion of Metals.

"Manufacture of Cast Iron Pipe," by D. B. Stokes, The United States Cast Iron Pipe and Foundry Co., Chicago.

The paper by Mr. Barton, in his absence, was read by E. F. Cone. J. B. Capron, acting for Mr. Stokes, explained the moving picture film on the manufacture of cast iron pipe.

Because of the interest shown in the papers on the use of electric furnaces, the following resolution was unanimously adopted:

Resolved, That this meeting recommends that the American Foundrymen's association shall at the next annual meeting arrange for the preparation and presentation of further groups of papers upon the metallurgical results that have and may be obtained through the use of the electric furnace and with reference to the value of alloying additions.

Sand Research—Testing Methods Session

Tuesday, May 1, 2 *p. m., Ball Room, Hollenden Hotel*

R. A. Bull, past president, American Foundrymen's association, and chairman Joint American Foundrymen's Association and National Research Council Committee on Molding Sand Research, presided as chairman. The following reports and papers were presented and discussed:

Report of Chairman of Joint Committee on Molding Sand Research.

Report of Subcommittee on Testing Foundry Sands.

"The Cohesiveness Test of Foundry Sands," by Dr. H. Ries and C. M. Nevin, Cornell University, Ithaca, N. Y.

"A Physical Test for Foundry Sands," by Eugene W. Smith, The Crane Co., Chicago.

Business Session

Tuesday, May 1, 4 *p. m., The Ball Room, Hollenden Hotel*

President C. R. Messinger presided at this meeting. The report of the secretary on the election of officers was the first business taken up as the reading of the minutes of the last meeting was dispensed with. The officers whose election was announced were as follows:

President G. H. Clamer, and vice president H. B. Swan. Directors elected to serve for the following three years were L. L. Anthes, T. S. Hammond, A. E. Howell, C. R. Messinger, and T. W. Pangborn.

The new officers present were introduced.

President-elect Clamer then spoke on the proposed trip of the American foundrymen to attend the International Foundry congress at Paris in September.

President Messinger next read a communication from the board of directors recommending the employment of a technical

secretary and proposing a plan of co-operating with local foundrymen's associations. No action was taken on these recommendations at this time.

The secretary next read a communication from the board of directors that at a meeting of the board on April 29, 1923, resolutions were unanimously adopted recommending to the association that C. R. Messinger, retiring president, Dr. G. K. Burgess, of Washington, D. C., and Dr. H. Ries, of Cornell university, Ithaca, N. Y., be elected to honorary membership in the association. These recommendations were unanimously approved at this meeting.

Past president A. E. Howell, as chairman of the committee on resolutions, then presented the following resolutions which were unanimously approved:

"In considering our indebtedness as members of the association, the subject seems to divide itself naturally into three considerations:

"First, our gratitude for the hospitality of Cleveland.

"Secondly, the press of Cleveland and the splendid journals devoted to furthering our industry.

"Thirdly, the obligation which we feel to our own officers and committees who have borne the heavy burden, which it really is, no matter how graciously and willingly they have offered themselves for the duties assigned them.

"It seems that the city of Cleveland is a magnet of such drawing power that at least once in each decade we find ourselves irresistably drawn to this wonderful center. In 1906 and again in 1916, it seemed a difficult matter to recount the advantages and progress of this magnificent city by the lakes. Now in 1923 the task of enumerating its progress and all phases of its industrial and educational and artistic advance, is hopeless, indeed, and being familiar to Clevelanders as it is to the world, we will be pardoned if we undertake no enumeration. But it is gratifying to us as members of the American Foundrymen's association, to note that progress in the iron and steel malleable and nonferrous castings to which industries we are de-

voted, has played no small part in this wonderful progress of Cleveland.

"It seems that its cognomen of "The Convention City" is most justly applied. The activities of all of the local committees, their concentrated efforts and devotion to the successful culmination of our convention, it is hopeless to adequately recognize in detail.

"To the chairman of each of these committees and their members, we feel deeply grateful and their efficiency seems to us to entitle Cleveland not only to be called the "Convention City" but the "City of Hospitality" in its broadest sense, with the latchstring on the outside and welcome ever smiling within.

"We frankly admit our reluctance to use terms of fulsome sound, but we desire in the simplest words without the use of superlatives, to convey our heartfelt appreciation.

"To the Press of Cleveland, to those marvelous trade journals, which by their daily publication and very numerous illustrations, their cartoons and their photographs, have given publicity to the scientific and technical importance of our activities and have at the same time welded the entire attendance into a wonderful feeling of good fellowship and the most genial atmosphere, we cannot overstate our admiration. Their energetic enterprise and the good humor which has prevaded all, gives the impression to those who read that it was a pleasure and never, merely duty, which actuated them.

"To Our Officers: It is always a problem to differentiate between the idea that they are merely doing what they should do, and the idea that what they have done, is without money and without price. They have unselfishly sacrificed themselves, and their personal interest to the general good. Our technical committees have grown in number and their ramifications into important phases of the industry, makes even their enumeration impractical. In a resolution to which you are compelled by courtesy to listen, we dare not begin an enumeration, lest by inadvertance we should omit honor to whom honor is due, or depreciate by too scant praise.

"To President Messinger and Vice President Clamer, we extend our admiration of the self-abnegation which has accompanied their efforts. This also applies particularly to the chairmen of the various committees whose hands have been held up by their various members. Those who are present with us will receive many individual expressions from their friends who know of the excellence of their achievements. Because he is not present, we make bold to mention the name of H. Cole Estep, chairman of "International Relations," who resides in London, England, and beg to convey to him, at this long range, our appreciation of the cordial relations that he has established and our hope that there will be many members of this association who will avail themselves of the hospitality of the English and French associations in the contemplated visit this summer to those climes.

"Because of the fact that our secretary, C. E. Hoyt is a paid official, some might think as he doubtless does, that to express appreciation of his work and that of his staff, were superfluous. But those on the inside are familiar with the magnitude of the problems accompanying such a great meeting and will appreciate that Mr. Hoyt is more than our "hired man" and that he does and accomplishes things that could not be done were he not imbued with the spirit and qualities which are born in the man and cannot be purchased and are seldom acquired.

"Despite upheavals and disturbances the progress of the world has been one of amelioration since the dawn of history, and so we feel that the advance of the American Foundrymen's association has with slight fluctuations, steadily approached this greatest of all achievements, the Cleveland convention of 1923."

President Messinger's remarks on the need for increased association membership concluded the meeting.

Sand Research Session—Geological Survey and Reclamation Topics

Wednesday, May 2, 9:30 a. m., Ball Room, Hollenden Hotel

R. A. Bull, past president, of the American Foundrymen's association, presided. The following reports and papers on the

subjects of geological survey of foundry sands and reclamation and conservation projects were read and discussed:

Report of Subcommittee on Geological Surveys of Foundry Sand Resources.

Report of Subcommittee on Conservation and Reclamation of Foundry Sands.

"Sand Conservation and Reclamation Tests Using the Doty Testing Machine," by R. F. Harrington, W. L. MacComb and M. A. Hosmer, The Hunt-Spiller Mfg. Corp., Boston.

"The Use of Chemical Reagents in the Preparation and Rebonding of Molding Sands," by H. W. Highriter, New Haven, Conn.

"Reclamation of Core Sand," by F. L. Wolf and A. A. Grubb, Ohio Brass Co., Mansfield, O.

"Reclaiming Foundry Sand," by H. M. Lane, Detroit.

"Brass Molding Sand Reclamation and Conservation Experiments," by F. L. Wolf and A. A. Grubb, The Ohio Brass Co., Mansfield, O.

Malleable Session

Wednesday, May 2, 2 p. m., Ball Room, Hollenden Hotel

H. A. Schwartz, Research Director of the National Malleable Castings Co., of Cleveland, acted as chairman. The following papers and report were presented and discussed:

"Application of Fuel Oil to the Malleable Air Furnace," by A. Van Landschoot, Iowa Malleable Iron Co., Fairfield, Iowa.

"Hardened and Tempered Malleable Castings," by Edwin K. Smith, Lakeside Malleable Co., Racine, Wis.

"The Application of the Dressler Tunnel Kiln for Annealing Malleable Castings," by Philip Dressler, American Dressler Tunnel Kilns, Inc., Cleveland.

"Malleable Iron Cast in Small Quantities," by S. J. Felton, Ohio Mechanics Institute, Cincinnati.

"Methods of Checking Malleable Scrap," by E. D. Halsey, Terre Haute Malleable & Mfg. Co., Terre Haute, Ind.

Report of Committee for Specifications for Malleable Castings.

Session on New Developments in the Foundry Industry
Wednesday, May 2, 2 p. m., The Lounge, Hollenden Hotel

A. E. Howell, past president of the American Foundrymen's association presided at this meeting. The following papers were read and discussed:

"Centrifugal Casting of Iron Piston Rings," by John A. Rathbone, Detroit.

"Centrifugal Castings," Leon Cammen, New York.

"The Desulphurization of Cast Iron," by Dr. Richard Moldenke, Watchung, N. J.

"British Foundry Practice, Ferrous and Nonferrous," by Dr. Percy Longmuir, Sheffield, England, Annual Exchange Paper of the Institution of British Foundrymen. This paper in the absence of the author was read by R. S. McPherron of the Allis-Chalmers Co., Milwaukee.

"A New Long Life Mold Development," by Dr. Richard Moldenke, Watchung, N. J.

Steel Session

Thursday, May 3, 9:30 a. m., The Ball Room, Hollenden Hotel

A. H. Jameson, Plainfield, N. J., in the chair. The following addresses and reports were read and discussed:

"Heat Treatment of Alloy Steel Castings," by H. A. Lorenz, Bucyrus Co., South Milwaukee.

"Annealing Steel Castings," by H. A. Neel, Michigan Steel Casting Co., Detroit.

"Core Mixtures for Light Steel Castings," by C. S. Koch, Fort Pitt Steel Casting Co., McKeesport, Pa.

Report of Committee on Refractories.

Report of Committee on Heat Treatment of Ferrous Castings.

Report of American Foundrymen's association representative on Joint Committee for the Investigation of Phosphorus and Sulphur in Steel.

Gray Iron Session

A. O. Backert, past president of the American Foundrymen's association, presided as chairman. The reports and papers listed below were read and discussed:

"Notes on Gray Iron for Automotive Castings," by H. B. Swan, Cadillac Motor Car Co., Detroit.

"Carbon in Cast Iron," by J. W. Bolton, Niles Tool Works, Hamilton, O.

Report of Committee on Specifications for Cast Iron.

"Visual Observation of Melting in a Cupola," by John Grennan, University of Michigan, Ann Arbor, Mich.

Annual Banquet

Wednesday, May 2, 7 p. m., Cleveland Hotel

President C. R. Messinger presided as toastmaster at the annual banquet which was attended by the largest number of guests that were ever present at a similar affair of the association.

After the opening remarks by the toastmaster, Ralph H. West, Chairman of the Cleveland Foundry Committee, was introduced and expressed on behalf of the Cleveland foundrymen their pleasure at having the association meet in their city for the third time.

President Messinger then introduced Emile Ramas, president of the Association Technique de Fonderie de France, who in his address invited the members of the American Foundrymen's association to be the guests of the French association at the International Foundry congress which was to be held in Paris in September. This invitation was acknowledged by President Messinger on behalf of the American Foundrymen's association, while President-elect Clamer reviewed the proposed trip in detail.

President Messinger next announced a gift of $1000 given to the Association by the American Foundry Equipment Co. through its president, Verne E. Minich. This fund was pre-

sented to the association to be used in connection with the molding sand research.

The principal speaker of the evening, Major General Henry T. Allen, was then introduced by John A. Penton. General Allen in his address made an urgent plea that the United States take a more active part in world affairs.

Transactions
of the
American Foundrymen's Association

Annual Address
By the President, C. R. Messinger

The thought uppermost in my mind, as I realize that the American Foundrymen's association year is drawing to a close and my term of office is about to expire, is the unusual support given the president of your association. Help and advice are given generously by the directors, the standing committees and several past presidents who still retain a very active interest in the association's welfare. I would be ungrateful and remiss in my duty if I failed to call the attention of the members to the very efficient and painstaking work of the secretary and his assistants throughout the year. The work of the committee on molding sand research deserves special mention and will be referred to later. This rather large committee under the chairmanship of R. A. Bull has, while raising money to help carry on its activities, done an enormous amount of original work; and its accomplishments are likely to mean much in the future to the foundry world. To all those who have worked so faithfully I want to express not only my own thanks and appreciation but those of the association as well.

Association Activities Greatly Increased

There is a tendency for all associations to increase their activities with the result that often too many things are attempted and too few well done. Possibly we have erred in this respect, but if so our mistakes have been relatively few as each year our technical sessions and work throughout the year have been of a higher order than of that preceding. It is a fact, however, that the volume of our technical work has in-

creased more rapidly than has our ability to handle it. Few technical associations have exhibits in connection with their annual meetings, and no other attempts anything that compares in magnitude with ours. The financial arrangements and the work of preparing and conducting the exhibition are so great that too large a proportion of Mr. Hoyt's time is taken from the truly technical work of the association. It has been suggested that the association employ a high-grade technical man whose whole time would be devoted to the association.

Technical Secretary Needed

I am heartily in accord with this suggestion. We are the body that represents the technical side of the foundry world, and when we consider the magnitude of this industry it should stimulate us to great accomplishments. If we stop and think of the improvements in foundry methods during the last fifteen years, it will help us to visualize the possibilities for the future. The basis for our development is the work of the chemist, the metallurgist, and the engineer, and the association must never neglect an opportunity to carry on research work of the highest order. In the past the members of the industry and those supplying it have been generous in their support of the association and this support will increase. I hope the association can without delay adopt the suggestion that we employ a technical secretary under whose direction will come all activities of a technical nature.

The Bulletin has completed its second year. Your officers feel that it has filled a need of the association, but that in time its scope can be broadened so that it may more comprehensively represent the various phases of association activity. More technical reports and references could then be included, together with resumes of committee activities, comments and suggestions by the membership, and other features which make it more representative of the industry. The bound volume of transactions covering the Rochester convention are now being distributed and it is regrettable that this could not have been in the members' hands at an earlier date. The delay has been due to an unusual situation in the printing establishment that has

always handled this work. The transactions of the present meeting will go out on time and will be a valuable addition to any technical library.

International Relations Established

This year a committee on foreign relations was organized with H. Cole Estep as chairman. Through the work of this committee and Mr. Estep, who is located in London, much has been done to keep in touch with the work of the associations similar to ours in England, France and Belgium. Last year we were honored by a visit from Oliver Stubbs, president, and Thomas Furth, a former president of the Institution of British Foundrymen. These gentlemen visited the foundry centers of this country and were the guests of the American Foundrymen's association. F. J. Cook was the official representative of this institution at the Rochester meeting. The paper presented by Mr. Cook and those prepared by E. Ronceray of the Association Technique de Fonderie de France and Joseph Leonard, president of the Association Technique de Fonderie de Liege, were valuable contributions, and made the International meeting one of the features of the convention. This year we will again exchange papers with the English and French associations. Emile Ramas, president of the Association Technique de Fonderie de France will be present at Cleveland and bring to us the greetings of French foundrymen. The establishing of more intimate relations with the technical associations of Europe is of national significance and nothing but good can result from work along these lines. If the technical associations of all countries will co-operate in a way that seems possible for us, perhaps it will help to eliminate some of the international misunderstandings of which we hear so much. Our work with the societies representing the foundry industry in Europe is a step forward and it is within the range of possibility that a great international convention can be held in conjunction with our 1926 meeting, which will celebrate the 150th anniversary of the Declaration of Independence.

Award Funds

At the Columbus meeting the association was the recipient of some generous donations from members. The proceeds of these donations are to be devoted to awards for work of merit in the industry. The handling of such large sums for future generations under conditions very different from those of the present, places a new responsibility on the association. Your directors have decided that this can best be done by a self-perpetuating board, and this board is being guided by the experience of other associations with funds of this kind. At present a deed of gift acceptable to the donors and to the association is being drafted and it is hoped that the funds can be properly safeguarded and yet give those who administer them in years to come the power to meet conditions as they find them and make awards which will meet the ideas of the very generous contributors. It is regrettable that it is impossible to make but one award this year, that is the Obermayer, but this failure cannot be attributed to the present board of awards. The situation now is a satisfactory one and the first awards will be made at next year's meeting.

Molding Sand Research

The molding sand research has been referred to before. Twenty-five hundred dollars had been contributed by the Pangborn Brothers and $1,000 by the National Engineering Co. to be used as the directors might designate for some useful advancement of the foundry industry. The directors, after careful thought, decided to utilize the funds in studying molding sands, which investigation was accordingly organized in December, 1921. All will remember the very great interest that attended the first reports of this committee at the Rochester convention. Since that time the committee has done a tremendous amount of work, largely along the line of developing satisfactory methods of testing sand. Such methods have been very seriously needed by the foundry industry which has been without any suitable means of comparison and selection.

Sand Test Methods Recommended

It now appears that methods have been finally developed which have been found sufficiently satisfactory to justify definite recommendation by the joint committee at this convention. The methods recommended as tentative for one year's trial include the three which are regarded by the joint committee as essential. They will determine bonding strength or cohesiveness, permeability, and fineness; and a method is recommended by the committee for the sampling of molding sands. Your president feels that the announcement regarding tests as well as the progress made in arranging for geological surveys and reclamation will be of great interest to foundrymen.

Attention can appropriately be called to the fact that this joint committee is of remarkable character, consisting as it does of 48 men officially representing not only the American Foundrymen's association but the National Research council, the American Society for Testing Materials, the United States bureau of standards, the United States bureau of mines, the Canadian department of mines and other organizations. The complete personnel of the joint committee includes grey iron foundrymen, steel foundrymen, malleable foundrymen, nonferrous foundrymen, sand producers, metallurgists, engineers, chemists, geologists, physicists, ceramists, refractory experts, and in fact all who have theoretical or practical information of value in the consideration of so large a problem.

Co-operation Received from Other Organizations

It is gratifying to state that these committees have been materially assisted by the work of many other investigators who have co-operated to splendid effect. Such assistance has come in marked degree from Cornell university and from the University of Illinois. The bureau of standards has been of vast help through membership of individuals like Dr. G. K. Burgess and his assistants in the metallurgical division of the Bureau. Dr. H. Ries, head of the department of geology at Cornell university, has, as chairman of the subcommittee on geological surveys, been of very great assistance in his work. These institutions and individuals are mentioned particularly because

of the assistance received from them despite the fact that they are not directly related to the foundry industry.

It will be plain from the foregoing that the committee's recommendations are entitled to very hearty endorsement by the foundry industry, which should exhibit keen appreciation of the service that is being rendered by these gentlemen without compensation. The chairman of the joint committee informs me of having just recently received at a most opportune time an unsolicited contribution of $1,000 from the American Foundry Equipment Co., to be applied to this work. More funds are needed now to permit the desired prosecution of certain phases of the work that have necessarily been delayed until satisfactory test methods could be developed. It is confidently believed that there will be no difficulty in securing needed sums to continue this investigation, which has marked a distinct step forward in scientific achievement by our association.

Local Groups Favored

With the growth of the industry in certain centers, local foundrymen's associations are being organized, and the fact that foundrymen are getting together locally is an indication that closer relationship is needed between our association and its individual members. Any movement which draws foundrymen together cannot be looked upon with disfavor by us, and yet anyone with vision, no matter how great his interests may be in a local organization, cannot but see the value of a strong national association. I am confident that a plan of local sections can be worked out that will benefit both the American Foundrymen's association and the local organization. A definite plan has not as yet been crystallized but it has been suggested that sections could be organized by us and that membership in the American Foundrymen's association would constitute membership in the local. Funds could be allotted to locals according to their activity and the number of members. The employment of a technical secretary as suggested would not only put us in position to help organize these locals, but we could through the year furnish technical information that would be helpful, and interest in the Amercian Foundrymen's association would

be stimulated during the year. I am sure that if we do our work well through locals from one annual meeting to another, there will be more interest and larger attendance rather than smaller at the annual meeting. Our membership would increase by this plan and from this increase funds would be available with which to help locals.

Labor Scarcity Grows

The scarcity of foundry workers presents a serious problem and statistics recently published by the National Industrial Conference board are of particular interest to us. Analysis of the immigration statistics for the first complete fiscal year of operation under the present law, shows that the number of immigrant aliens admitted was approximately 309,556, and the number leaving was approximately 198,712, making the net increase in population by immigration 110,844. This figure is less than one-fifth of the gain in the year preceding the present law becoming effective. This figure is even more significant when it is considered that of 110,833 increase, 104,326 were women and children and only 6,518 men. Considering both immigrant and nonimmigrant aliens admitted and departed, the first fiscal year's operation of the law shows a net loss of 11,687 males to the country. On the other hand, in September, 1922, there were 6,181 foundries in the United States, which is a gain of 217 in the past two years.

Shop Conditions Should be Improved

A foundry's proportional expenditure for labor compared to its output is much higher than that of the average manufacturing plant. This means that many men are employed. With the tendency toward unrest and dissatisfaction among our people, we, if for no other reason that our own welfare, are obligated to do our part and see that working conditions in our foundries are what we know they should be. Under anything like normal business conditions we always have a labor shortage, and this condition will grow worse rather than better until the present law is amended. The American Foundrymen's association should stimulate invention and encourage the use of labor saving machinery. In the past we have played our part

in the great safety movement, and in the future our aid in removing as far as possible the heavy and frequently too burdensome jobs. This phase of the foundry will have even more prominence in the next decade than it has in the past. If this is to be so it is well for us to recognize it at an early date, and so shape our policy that we may offer the greatest help to our members in meeting their every day operating problems.

Pattern Standardization Needed

Standardization of pattern equipment opens another field of endeavor. The majority of our members are connected with so-called jobbing shops and know too well the difficulty of getting pattern equipment that can be used in connection with molding machines. It is medieval to use hand labor when it can be done by machine, thus releasing men for other work, and yet it is very often necessary because the purchasers of castings will not make the necessary expenditure to obtain proper patterns and equipment. We sometimes forget that foundrymen and manufacturers of equipment have many different standards and that buyers of castings are often put to needless expense when changing patterns from one shop to another. There is need for pattern standardization and in this we should take the lead. If funds can be secured to insure a two or three year's study of the subject, we will be in position to obtain much data that has already been collected. We cannot correct all the evils of the industry at one time, but we can recognize them and plan to take them up in a logical way.

Membership Should be Increased

The increase in membership in the past has been gratifying, but we suffered, as did most organizations of a similar character, during the period of retrenchment. Your officers and directors have many plans which are dependent upon a large membership and the resulting income. All thoughts for the future are based upon helping our industry and I believe the twenty-seven years of service rendered by the American Foundrymen's association puts an obligation of membership on any man who expects to make his lifework the foundry. A survey

of attendance shows that many attend our annual meetings who are prominent in the industry but are not members. All are welcome, but we the members should realize that our association has a record of accomplishment and much to be proud of, and if this thought is broadcasted many of the thoughtless ones will realize that they owe us their support. We should show a continued increase in membership and interest, and should accomplish more in the future than in the past.

In closing I want to express my appreciation of the opportunity I have had of working with the present board of directors. Their willingness to give of themselves without stint, and their unselfish devotion to the interests of the association and the industry, have made the work with them a privilege.

Annual Report of the Board of Directors

To the Members of the American Foundrymen's Association, Inc. Gentlemen:

We submit herewith for the board of directors, a report covering the meetings of the board from Oct. 3, 1922, to Dec. 31, 1923. During this period there were five meetings, and we give a brief summary followed by the full minutes of each meeting.

The first meeting was held on Oct. 3, 1922, at Chicago, when the board elected at the annual meeting in Rochester in June, with President Messinger in the chair, organized by electing a secretary-treasurer, manager of exhibits, assistant secretary, and executive committee.

A report was received from the special committee appointed at Rochester to consider American Foundrymen's association policy in co-operation with other associations in the adoption of an international test bar for cast iron.

Important action was the creating of a permanent board of awards, consisting of the seven last living past presidents, in whose hands was placed the administering of all award funds.

The next meeting was held at Cleveland, April 29, 1923, the day preceding the opening of the annual convention. The meeting followed the annual alumni dinner of officers and past officers of the association, and at this meeting it was voted to recommend to the members at the annual meeting of the association, that C. R. Messinger, Dr. G. K. Burgess, and Dr. H. Ries, be elected to honorary membership.

The next meeting of the board was held June 19, 1923, at Chicago. This was the final meeting of the 1922-23 board. Reports of the secretary-treasurer and manager of exhibits were received.

A report for the committee on international test bar was submitted with recommendations which were approved.

A report of the meeting of the board of awards, held June 18, with recommendations for giving medals at the 1924 conven-

tion was received. This report which included the recommendation that the award fund bonds totaling $21,000, be placed with the Harris Trust & Savings Bank, Chicago, as trust agent, was approved.

A report of the committee on foundry costs, with recommendations for cost activities were received.

Major R. A. Bull, chairman of the committee on molding sand research, asked to be relieved of the chairmanship. The appointment of a successor was referred to the executive committee.

Mr. Clamer submitted a report for the committee on international relations, advising that arrangements had been made for the American Foundrymen's association delegation to attend the International Congress of Foundrymen at Paris.

The recommendation of the finance committee, that $3000 be transferred from the funds of the department of exhibits to the funds of the technical department was approved.

The result of the annual election of officers and directors, which was confirmed at the annual meeting in Cleveland on May 1, was read and made a matter of record.

Immediately following the adjournment of the preceding meeting the new board was called to order by President Clamer in the chair.

H. B. Swan, who was elected vice president stated he would find it necessary to tender his resignation as vice president and director. L. W. Olson was elected vice president to fill the vacancy caused by Mr. Swan's resignation, and Edward W. Beach was elected a director to fill the vacancy caused by Mr. Olson being elected to the office of vice president.

The board then proceeded to complete its organization by electing a secretary-treasurer, manager of exhibits, and assistant secretary and executive committee. Salaries of officers were fixed.

A resolution was passed authorizing the secretary-treasurer to place the $18,000 in United States government bonds, representing the sinking fund of the department of exhibits, with the Harris Trust & Savings Bank, Chicago, as trust agent.

Provision was made for the election of four members of the nominating committee, in accordance with provision of Article IX, Section 1 of the by-laws.

On motion the president was authorized to appoint a committee to which would be referred questions of policy in intersociety relations.

The next meeting of the board was held in New York City, on November 20, 1923. All members but one were present.

It was voted that the next annual convention and exhibit of the association should be held in the fall of 1924, and a committee on location was appointed.

A contribution of $250 to the Institute of Metals Division of the American Institute of Mechanical Engineers was authorized.

A report of the joint committee on molding sand research was received.

A contribution of $500 from Rogers, Brown & Co., Cincinnati, for research work, was announced, and resolutions of appreciation were authorized.

Cost committee activities were discussed and fundamental principles approved.

Regulations governing papers were adopted.

Reports of the International Foundrymen's Congress at Paris were received, and resolutions of appreciation of the hospitality shown in England, France, and Belgium were authorized. A resolution expressing appreciation of the splendid work of H. Cole Estep, as European representative of the American Foundrymen's association was unanimously adopted.

Full minutes of all board meetings follow.

Respectfully submitted,

C. E. HOYT, *Secretary-Treasurer.*

For the Board of Directors.

Minutes of Meetings of Board of Directors

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION, DRAKE HOTEL, CHICAGO, TUESDAY, OCT. 3, 1922.

The first meeting of the 1922-23 board of directors of the American Foundrymen's association was called to order by President C. R. Messinger in the chair.

The following directors were present:

C. R. Messinger, H. R. Atwater, A. O. Backert, R. A. Bull, G. H. Clamer, Fred Erb, S. T. Johnston, V. E. Minich, C. B. Connelley, L. W. Olson, A. B. Root Jr., and C. E. Hoyt. Assistant Secretary Robert E. Kennedy, B. D. Fuller, and L. W. Mueller were also present.

Absentees: S. B. Chadsey, C. S. Koch, Alfred E. Howell, and W. A. Janssen.

The chair announced a quorum present.

In calling the meeting to order President Messinger expressed appreciation of the honor which has been conferred upon him in his being elected president of the American Foundrymen's association, and expressed the hope that he would successfully continue the work which has been so ably carried on by his predecessors.

Mr. Messinger then called up Vice President Clamer, who in a few words expressed appreciation of the honor which had been conferred upon him, and said it would be a pleasure to support the president and to serve the association to the best of his ability.

Mr. Messinger also introduced and welcomed the new directors, Messrs. C. B. Connelley, L. W. Olson, and A. B. Root Jr.

The chair announced that the first order of business would be the election of a secretary. Mr. Minich moved that the offices of secretary and treasurer be combined as provided for in Section 1, Article 3 of the by-laws. Motion prevailed.

Mr. Minich then nominated C. E. Hoyt for the office of secretary-treasurer. Mr. Clamer seconded the nomination and moved that the nominations be closed and that the president be instructed to cast the unanimous ballot of the directors for C. E. Hoyt as secretary-treasurer. Motion prevailed, whereupon the chair announced that the ballot had been cast, and declared C. E. Hoyt duly elected secretary-treasurer of the association for the ensuing year.

The chair announced that the next order of business would be the election of a manager of exhibits. Mr. Atwater nominated C. E. Hoyt as manager of exhibits. Motion seconded by Mr. Bull, who moved that the president be instructed to cast the unanimous ballot of the board for C. E. Hoyt as manager of exhibits. Motion prevailed, whereupon the chair announced that the ballot had been cast, and declared C. E. Hoyt duly elected as manager of exhibits of the association for the ensuing year.

The chair announced that the next order of business would be the election of four members of the board, who together with the president, vice president and secretary would constitute the executive committee of the board, and appointed Mr. Backert and Mr. Root as a committee to nominate members for the executive committee.

Mr. Backert and Mr. Root conferred together, and reported the

nomination of R. A. Bull, Fred Erb, S. T. Johnston, and L. W. Olson. There being no other nominations, Mr. Backert moved that the secretary cast the unanimous ballot of the board for the four men named. Motion prevailed, whereupon the chair announced that R. A. Bull, Fred Erb, S. T. Johnston, and L. W. Olson, together with the president, vice president and secretary would constitute the executive committee of the association for the ensuing year.

The chair announced that in accordance with the revised by-laws it would be necessary for the board to prescribe the method of election, by letter ballot of the members, of four members of the nominating committee, who together with the last three living past president would constitute the committee to nominate officers and directors in accordance with the by-laws of the association.

It was moved that the names of ten active members of the association who are not past presidents or directors, and who are representative of the various branches of association activities, be submitted to the members for mail ballot four months prior to the first day of the annual convention in 1923, and that the four members receiving the highest number of votes be declared elected members of the nominating committee, and the four next highest, alternate members of the committee. It was further moved that an announcement be printed in the bulletin inviting members to suggest names for the nominating committee ballot. Motion prevailed.

Mr. Clamer reporting for the finance committee stated that the committee had been considering the salary budget for the coming year. He made a general statement of salaries for the past year, and then moved that the salary of C. E. Hoyt as secretary-treasurer of the association be continued at $200.00 per month. Motion seconded by Mr. Minich and carried.

Mr. Clamer moved that the action of the executive committee in arranging for the part time services of R. E. Kennedy of the University of Illinois, at a salary of $150.00 per month, as assistant to the secretary, and secretary of the papers committee, be confirmed. Motion seconded and carried.

Mr. Clamer moved that the salary of E. L. Shaner at $100.00 per month, with a stenographic allowance of $20.00 per month, be continued until the work he is doing on the bound volume of Transactions is completed. Motion seconded and carried.

Mr. Clamer moved that the salary of C. E. Hoyt as Manager of exhibits be continued at $7,600.00 annually, to be paid out of the funds of the department of exhibits. Motion seconded and carried.

Mr. Clamer moved that Miss Reininga's salary of $175.00 per month be paid as follows: $100.00 from the funds of the department of exhibits, and $75.00 out of the funds of the technical department. Motion seconded and carried.

Mr. Clamer moved that 50 per cent of the traveling expenses of the members of the board and the executive committee be paid by the technical department, and 50 per cent by the department of exhibits, for attendance at all meetings except meetings held during convention week; and further that all traveling expenses of members of the papers committee and other standing committees of the technical department be paid entirely out of the funds of the technical department, and that the traveling expenses of members of the convention and exhibits committee be paid entirely out of the funds of the exhibit department. Motion seconded and carried.

Mr. Clamer moved that the action of the officers in reimbursing Dr. Burgess of the bureau of standards for expenses incurred on account of sand research committee meetings be confirmed and that H. B. Hanley and Dr. H. Ries be reimbursed for personal expenses incurred on account of this work as recommended by Mr. Bull in his report; and further that the board authorized the reimbursement of any member of the sand research general and sub committees for expense incurred and for which they would not be reimbursed by their principals. Motion prevailed and it was so ordered.

The following resolutions were offered:

RESOLVED: That C. R. Messinger as president, C. E. Hoyt as secretary-treasurer, are hereby authorized to sign checks and draw against funds deposited in the Harris Trust & Savings bank, Chicago, Standard Trust & Savings bank, Chicago, and the Central National Bank Savings & Trust Co., Cleveland, Ohio, in the name of the American Foundrymen's Association.

RESOLVED: That the president and secretary-treasurer be authorized to make necessary arrangements for a special convention fund sufficient to take care of payroll and necessary expenses during the convention and exhibit period, and further that they be authorized to continue the petty cash expense fund of $200.00 to take care of small items of expense, said fund to be reconciled at the end of each month with a full statement of expenditures.

Mr. Minich moved that the resolutions be adopted. Motion prevailed.

Mr. Bull moved that the president and secretary be authorized to engage the services and fix the salaries of assistants, stenographic and clerical help, etc., deemed necessary to transact the business of the association. Motion prevailed.

Mr. Connelley moved that the executive committee elected by this board be given full power to act for the directors in the interim between meetings during the year. Motion prevailed.

Mr. Clamer moved that R. A. Bull and W. R. Bean be appointed as A. F. A. representatives on the committee on ferrous metals advisory to the bureau of standards. Motion prevailed.

The secretary read an invitation from the Association Technique de Fonderie of France, inviting the A. F. A. to join with the French, British, and Belgian foundrymen's associations in an international convention and exhibit in Paris the first fortnight in September, 1923. Following consideration of the subject it was moved that the invitation be accepted and referred to a committee to be appointed by the president. Motion prevailed.

It was moved that a committee on International relations be added to the list of standing committees, and that to this committee should be referred the details of A. F. A. cooperation in the International convention in Paris, September, 1923. Motion prevailed.

The chair stated that the next important question would be the consideration of the Association's co-operation in promoting the adoption of an international test bar and the use of pig iron by its analysis only, which was before the board by reason of a resolution which was presented at the Rochester convention.

Mr. Messinger stated that when this resolution was presented at the board meeting on June 6, the president was authorized to appoint a mittee of three directors with full power to investigate and make recommendations to the board, and that President Bean had appointed on this

committee R. A. Bull, C. E. Hoyt, and C. R. Messinger. The chair then called on Mr. Bull for a report.

Mr. Bull in submitting the report stated that the committee considered this a very important subject, and that because of our recently completed plan of co-operation with the A. S. T. M. it was advisable that we work very closely with them. Mr. Bull stated further, that recently we had received from the Association Technique de Fonderie of France an invitation to appoint members on an international committee to consider the size of testing pieces, which was the direct result of a paper read by E. V. Ronceray at the meeting of the I. B. F. in Birmingham last June. In the invitation to representation on this committee the following statement was made:

"It cannot be questioned that at present, in order to determine international specifications for castings, it is too early, but the A. T. F. strongly recommends that a committee be immediately formed between the interested societies to decide if the sizes of testing pieces proposed by Messrs. Fremont and Portevin cannot be adopted by all foundrymen with a view to rendering comparable tests made in different countries, and when decided, to investigate the value of the sounding test, and to carry out experiments and collect data from members, with a view to reporting results at a joint foundrymen's meeting."

Mr. Bull pointed out that the fact that a similar movement was started on the other side looking toward standard international specifications at about the same time a movement looking toward the adoption of a international test bar was started in this country, made advisable careful investigation that close co-ordination might be achieved.

Mr. Backert moved that the report of the committee be accepted, that G. H. Clamer be added, and the committee continue with power to act, and further, that in the event of a joint committee with the A. S. T. M., representation of the A. F. A. should not be subordinated to representation of the A. S. T. M. on that committee. Motion prevailed.

Mr. Bull moved that the invitation from the Association Technique de Fonderie be received and that the president be authorized to name A. F. A. representatives on this committee, if, after negotiations have proceeded further, it has deemed advisable to do so. Motion prevailed.

The chair called attention to the fact that the report of the committee on awards, which had been received at the morning session, had been referred to the new board, and should now be considered.

After an interesting discussion Mr. Clamer offered the following resolutions:

RESOLVED: That a permanent board of awards be established which shall consist of the last seven living past presidents of the American Foundrymen's Association, Inc., which board will be self-perpetuating as each retiring president becomes a member, taking the place of the senior past president on said board. The junior past president shall be the chairman.

BE IT RESOLVED FURTHER, That in the event that there should be at any time less than seven living past presidents on the board of awards, said board shall have the power to elect members of the Association to fill the vacancies, and

BE IT RESOLVED FURTHER, That the board of awards shall prepare articles of agreement for the several donors for the acceptance of said funds in the name of the American Foundrymen's Association, Inc.,

and shall have full power to carry out all the provisions thereof subject to the approval of the board of directors, as provided for in Article 6, Section 1 of the by-laws.

On motion the above resolutions were unanimously adopted.

Mr. Clamer moved that the board of directors recommend to the board of awards that at least three major awards be made at the 1923 convention, and that it is the sense of this meeting that it would be appropriate to recognize the life work of men who had contributed to the advancement of grey iron, malleable, and steel foundry practice. Motion seconded by Mr. Root and carried.

The secretary reported that many invitations had been received for the 1923 convention and exhibit but that the only cities which had supported these invitations with data showing what exhibit space was available, meeting room, and hotel accommodations, were Chicago, Cleveland, and Milwaukee. The secretary explained briefly the character of the accommodations in these different cities, after which it was moved that a special committee be appointed by the president with full power to act for the board in selecting the place and naming the time for the 1923 convention.

The question of creating sectional groups in the Association such as a steel section, malleable section, non-ferrous section, wtih a view to view to creating larger responsibility among the members and greater interest, was discussed. It was moved that this question be referred to the executive committee with power to act. Motion prevailed.

Mr. Connelley, chairman of the committee on Industrial Education nad Training of Apprentices, spoke earnestly on the difficulties the committee had experienced in arousing the interest of foundrymen to the importance of this great subject, stating that he was not discouraged, and believed that before the end of another year the committee could report progress.

The secretary called attention to the vacancy on the board caused by the death of J. P. Pero, whose term would have expired in 1923, and that the by-laws provided in case of vacancies on the board, that they should be filled by the directors.

The chair then announced that nominations would be in order. Mr. Clamer nominated S. Griswold Flagg III, of Philadelphia, and Mr. Bull seconded the nomination. There being no further nominations it was moved that the nominations be closed and that the secretary be instructed to cast the unanimous ballot of the board for Mr. Flagg. Motion prevailed. The ballot was cast, whereupon the president announced that S. Griswold Flagg III had been duly elected a director for the unexpired term of J. P. Pero.

On motion the meeting adjourned at 6:55 P. M.

Approved June 19, 1923.

Respectively submitted,
C. R. MESSINGER, President.
C. E. HOYT, Secretary.

MINUTES OF MEETING OF BOARD OF DIRECTORS, WADE PARK MANOR, CLEVELAND, FOLLOWING ALUMNI DINNER, APRIL 29TH, 1923

The following officers and directors were present: C. R. Messinger, G. H. Clamer, A. O. Backert, R. A. Bull, S. B. Chadsey, Fred Erb, Alfred E. Howell, S. T. Johnston, C. S. Koch, V. E. Minich, L. W. Olson and C. E. Hoyt.

The following members of the advisory board were present: L. L. Anthes, B. D. Fuller, H. D. Miles, Dr. Richard Moldenke, John A. Penton, and Chris Wolff; also Thomas W. Pangborn, director elect.

The meeting was called to order by President Messinger. It was moved that the reading of minutes of previous meeting be waived.

President Messinger appointed as members of the committee on resolutions for the Twenty-Seventh annual convention, Alfred E. Howell, E. F. Cone and A. E. Hageboeck; and as a committee on the Obermayer Prize, Pat Dwyer, A. J. Tuscany and Robert Barr.

The secretary read a communication from Mr. Hollinworth, secretary of the Institute of British Foundrymen, extending an invitation to members of the A. F. A. to be the guests of the I. B. F. when in route to the convention in Paris. It was moved that this letter be acknowledged with appreciation.

Mr. Clamer for the committee on International relations read a letter from Mr. Flagg, vice chairman, reporting progress for the proposed visit to the convention in Paris in September. It was moved that consideration of the full report of the committee on international test bar be put over until the June meeting of the board.

The board voted approval of the secretary's attending the Paris convention if later it was found advisable for him to do so.

A communication was read from a committee of the Foundry Equipment Manufacturers' Association suggesting consideration of the question of holding exhibits bi-annually. The president was instructed to appoint a committee to confer with the committee of the F. E. M. A. and appointed Messrs. G. H. Clamer, C. S. Koch, L. W. Olson and C. E. Hoyt.

It was voted that Miss Reininga be given a three months' leave of absence.

Plans for increasing membership during the convention were discussed and the president appointed Messrs. Erb, Howell, and Pangborn as a committee on membership for convention week.

Mr. Clamer read a report for the committee to co-operate with the A. S. T. M. It was moved that the report of the committee be accepted and the committee discharged.

Following the discussion on the subject of engaging a full time technical secretary, it was moved that this question be referred to the executive committee with full power to act.

Mr. Bull moved that the board recommend to the Association at the annual meeting that C. R. Messinger, retiring president, be elected to honorary membership. The secretary put the motion, which prevailed unanimously.

Mr. Bull moved that the board recommend to the Association that Dr. G. K. Burgess, director of the United States bureau of standards, be elected to honorary membership. The motion prevailed.

Mr. Bull made a further motion that the board recommend to the Association that Dr. H. Ries, professor of geology at Cornell university, be elected to honorary membership. The motion prevailed

Following a general discussion on Association activities, the meeting of the board was adjourned.

Approved June 19, 1923.

Respectively Submitted,
C. R. MESSINGER, President
C. E. HOYT, *Secretary.*

MINUTES OF MEETING OF THE BOARD OF DIRECTORS, A. F. A., DRAKE HOTEL, CHICAGO, TUESDAY, JUNE 19, 1923.

Roll call showed the following present: C. R. Messinger, president; G. H. Clamer, vice president; C. E. Hoyt, secretary-treasurer; directors S. T. Johnston, A. O. Backert, R. A. Bull, C. S. Koch, C. B. Connelley, Fred Erb, L. W. Olson, and W. A. Janssen, (V. E. Minich came in shortly after roll call) Assistant Secretary R. E. Kennedy, directors elect L. L. Anthes, T. S. Hammond, Thomas W. Pangborn, and H. B. Swan; Past presidents W. R. Bean and B. D. Fuller were also present.

Minutes of board of directors meetings of Oct. 3, 1922, and April 29, 1923, were read and approved.

The secretary read his annual report to the board. The report was accepted and ordered filed.

Mr. Clamer moved that the secretary be instructed to express to the American Foundry Equipment Company the appreciation of the board and of the Association for their generous donation of $1,000.00 to the research fund. Motion was seconded and carried.

Mr. Hoyt read the annual report of the treasurer. The report was accepted and referred to the finance committee.

Mr. Hoyt presented his annual report to the board, as manager of exhibits, presenting a detailed statement of receipts and expenditures from Aug. 31, 1922, date of the last audit, to June 15, 1923, supplementing this with a comparative statement of receipts and expenses for the past five exhibits. The report was accepted and referred to the finance committee.

Reporting for the executive committee the secretary stated that no meetings of the committee had been held since the last annual meeting, all business being transacted by correspondence.

Mr. Clamer presented a report for the committee on international test bar, and in concluding moved that it be the sense of this board that the proper method of procedure for handling international projects in the matter of specifications both of test bars and the analysis of pig iron be in co-operation with the A. S. T. M. and that the A. S. T. M. and the A. F. A. be joint sponsors for the standard specifications to be submitted to the American Engineering Standards committee, and that the American Engineering Standards committee be requested to co-operate with foreign engineering standardization bodies. Motion prevailed.

The secretary reporting for the board of awards stated that at a meeting of the board held June 18, the board received the report of the judges for the Obermayer Prize contest at the Cleveland convention and voted to recommend to the board of directors that prizes be awarded to Hugh A. Mackie and Charles Parsons, of the Homestake Mining Co., Lead, S. D., and that the secretary be instructed to purchase for each of the winners clocks on which should be placed a silver plate bearing an appropriate inscription, the total cost not to exceed $80.00

It was further reported that the board of awards had referred the question of medals to a committee of three with authority to secure designs and enter into contracts for making necessary dies for the four medals, the obverse side of each medal to be the same with the wording "American Foundrymen's Association Award," and on the reverse side of one "The J. S. Seaman Medal of the American Foundrymen's Association," with space for engraving the name of the person to whom the medal is awarded, and the date, and to secure similar

dies for the reverse sides of the John A. Penton, W. H. McFadden, and J. H. Whiting Medals, and that the committee also be authorized to decide upon the design and have the necessary plates made for an appropriate certificate to accompany each of the major awards.

The board of awards voted to recommend to the board of directors, that all the bonds, totaling $21,000.00, representing the principal contributed for award purposes, be turned over to the Harris Trust & Savings bank as trust agents for the Association.

It was further reported that the awards board had voted to award the first John A. Penton medal of the American Foundrymen's Association to Enrique Touceda, in recognition of the contributions he has made to the malleable casting industry, and that the first J. H. Whiting medal of the American Foundrymen's Association be awarded to John Howe Hall, in recognition of his contributions to the steel casting industry, presentations to be made at the 1924 convention.

The board of awards considered provisions for making a W. H. McFadden medal award, and voted that if at the 1924 convention a paper of outstanding merit be presented, a W. H. McFadden medal of the Association should be given to the author in recognition of such contribution, presentation to be made at the 1925 convention of the Association.

Mr. Connelley moved that the board of directors ratify and approve the report of the board of awards. Motion prevailed.

Mr. Minich moved that the necessary resolutions be prepared for placing with the Harris Trust & Savings Bank, a corporation organized under the laws of the State of Illinois, as agent and attorney in fact, all bonds representing the awards principal contributed for awards purposes, and that the interest coupons on these bonds be deposited as soon as they become due in the awards interest funds of the Association, withdrawals from this account to be upon the joint signatures of the president and treasurer, and withdrawals of any principal from the awards trust funds to be only upon the joint signatures of the president and treasurer upon showing a vote of the board of directors authorizing such withdrawal. Motion prevailed.

The secretary reporting for the committee on foundry costs read the minutes of the committee meeting held in Chicago April 6, 1923. At this meeting the committee decided that certain fundamental principles for determining foundry costs should first be agreed upon. Seven fundamentals were discussed and approved, whereupon it was moved that the committee adopt the following resolutions:

"RESOLVED: That the cost committee of the American Foundrymen's Association recommend to the president and board of directors of the Association that a suitable man be selected or employed by the Association, with authority to appoint others to act under him, to devote his entire time formulating and installing cost systems in the foundries of members, based on the principles advocated and endorsed by the Association."

In the report the chairman stated that the fundamental principles agreed upon had been submitted to various foundry associations and to foundry cost accountants, including T. W. Howard, cost accountant of the chamber of commerce of the U. S. A., with the result that they had been quite generally approved by all.

The report closed by recommending that a cost section of the A. F. A. be created as a separate branch of Association activity under the direction

and control of the main body, and offering suggestions as to how the cost work could be financed.

Following discussion it was moved that the report be received and appreciation expressed for the work the committee had done and that they be informed that in the judgment of the board it is not advisable for the Association to undertake the plan proposed in the report for the employment of a man to put this machinery in operation. And further that the board would heartily welcome a study of principles of cost accounting and the presentation of this subject to the members in such manner as could properly be done through bulletins and transactions of the Association. Motion prevailed.

It was moved that the matter of holding cost sessions at the annual convention and other matters of policy in connection with this work be referred to the executive committee to report back to the board at some future time.

The meeting adjourned for luncheon at 12:35 P. M.

The board reconvened at 2:15 P. M. President Messinger in the chair.

R. A. Bull, chairman of the joint committee on molding sand research submitted a verbal report reviewing the work of the past year. Mr. Bull stated that the committee as now created consists of forty-eight members, about one-half of whom are members of three sub-committees and of the executive committee.

Mr. Bull stated that the report of the committee presented in mimeograph form at the Cleveland convention was now being edited and that cuts had been made for illustrating the testing equipment, and that he would recommend that the report be printed in pamphlet form with a prefatory statement outlining briefly how the committee came to be organized, how it is constituted and how it functions. Mr. Bull stated further that arrangements were being made to have members of the executive committee address local foundrymen's associations on the work of the joint committee, and that several members had volunteered to undertake to do this in their sections of the country.

Mr. Bull stated further that during the summer surveys would be conducted in thirteen or fourteen states by the geological survey departments of the respective states, for the purpose of trying to develop deposits of molding sand that have not been heretofore developed, the work to be done at state expense, and samples from these surveys to be sent to the bureau of standards, Cornell university, and the University of Illinois, to be tested in accordance with methods approved by the committee.

Mr. Bull stated that some time previous to the Cleveland convention he had notified the president and secretary, and others that it would be necessary for him to give up the work as chairman of the sand research committee as soon after the Cleveland convention as a successor could be found. He stated that he was reluctant to give up the work, which he had enjoyed, but that it would be necessary to do so.

In closing Mr. Bull made special mention of the hearty and splendid support he had had from sub-committee chairmen Fred Wolff, H. B. Hanley, and Dr. H. Ries, each of whom had done a tremendous amount of good work at great personal sacrifice to themselves.

On motion the report was accepted, and president Messinger expressed to Mr. Bull for the board, appreciation of the work done and the very great regret which all felt that circumstances were such that it was necessary for him to tender his resignation.

Mr. Clamer made a verbal report for the committee on international relations, stating it had been learned that elaborate preparations were being made in Great Britain, France, and Belgium for the reception and entertainment of A. F. A. members who would make the trip. He stated that definite reservations for the trip were disappointing, as thus far only fourteen, including ladies, had made reservations, and urged that every effort be made to induce others to go.

Mr. Clamer read a telegram which had just been received from Oliver Stubbs, president of the I. B. F., as follows:

"British foundrymen assembled twentieth annual meeting Manchester send heartiest greetings to American foundrymen. Hope to see many of you in September."

Supplementing Mr. Clamer's report Mr. Bull read a letter from Mr. Estep urging that Mr. Hoyt as secretary of the A. F. A. be a member of the delegation. Mr. Minich moved that Mr. Hoyt as secretary of the A. F. A. be instructed to attend the Paris convention. Motion prevailed.

Mr. Clamer as chairman of the committee to confer with the committee from the Foundry Equipment Manufacturers' Association on the subject of holding exhibits bi-annually, reported that he was unable, both at the Cleveland convention and since that time, to arrange for a conference with Mr. Bougher, chairman of the committee for the F. E. M. A., but that just before leaving Philadelphia he had received a letter from Mr. Bougher, which he read. Following Mr. Clamer's report it was moved that the committee be continued and hold itself in readiness for a joint conference at any time mutually agreeable to the members of the committees representing the two associations.

At this point the chair called for the report of the finance committee consisting of R. A. Bull, A. O. Backert, and C. S. Koch. Mr. Bull in submitting the report stated that the committee had examined the auditor's reports of the exhibit department of Aug. 31, 1922, and of the technical department of Dec. 31, 1922, which were the usual periods for auditing the books of the two departments; that they had examined the treasurer's reports of receipts and disbursements since the audits and found them satisfactory.

Analysis of the reports of the department of exhibits showed $18,000 in U. S. bonds in the reserve fund, $14,273.00 in bank, and $1820.00 in accounts receivable, making a total of liquid assets for the department of exhibits of $34,093.00, with no bills payable.

The report of the treasurer for the technical department showed a cash balance on hand on June 15, of $4,125.07.

Mr. Bull stated that the committee in submitting their report would make the following recommendations:

1. That a bonus of $1000.00 be given to C. E. Hoyt, manager of exhibits, as a special recognition of valuable service in connection with the 1923 convention and exhibit, said bonus to be paid from the funds of the department of exhibits.

2. That hereafter the audit of both the technical and exhibit accounts should be made annually as of date of Dec. 31, to be accompanied by a final consolidated statement of all financial activities of the Association.

Mr. Bull moved the acceptance of the report which was duly seconded and carried.

The question of the usual transfer of funds from the exhibit department to the support of technical department activities was discussed, following which it was moved that the transfer of the sum of $3000.00 be made forthwith. Motion prevailed.

The secretary announced that at the annual meeting of the Association in Cleveland, Tuesday, May 1, members present acting upon the recommendation of the board of directors, elected the following to honorary membership in the Association: C. R. Messinger, the retiring president, Dr. H. Ries, professor of geology, Cornell university, and Dr. G. K. Burgess, director of the U. S. bureau of standards. The secretary read letters of acceptance which had been received from Dr. Ries and Dr. Burgess.

The secretary reported that at the annual meeting of the Association in Cleveland, Tuesday, May 1, 1923, the election of the following officers was confirmed by the members present:

For president and director for one year, G. H. Clamer, of the Ajax Metal Co., Philadelphia, Pa. For vice president and director for one year, H. B. Swan, of the Cadillac Motor Car Co., Detroit, Mich. For directors for three year terms: L. L. Anthes, Anthes Foundry, Ltd., Toronto, Ont.; T. S. Hammond, Whiting Corporation, Harvey, Ill.; Alfred E. Howell, Somerville Stove Works, Somerville, N. J.; C. R. Messinger, Chain Belt Co., Milwaukee, Wis.; Thos. W. Pangborn, Pangborn Corporation, Hagerstown, Md.

President Messinger stated that if there was no further business to come before the retiring board, he would turn the business of the Association over to the new board with very best wishes to President-Elect Clamer for a successful administration.

Mr. Messinger then introduced Mr. Clamer as the new president. In response Mr. Clamer stated that he appreciated the honor of having been elected to the presidency of this great association, and that so far as he knew he was the first president to come from the ranks of the non-ferrous industry; that he succeeded a long line of capable, energetic, sincere, and prominent men in the industry, each of whom had added his own step of individuality in the march of progress that had brought the Association to its present standing among associations not only of this country, but of the world, and that it he could add his own little step in that forward march of progress he would be content.

President Messinger declared the meeting of the board adjourned and announced that a meeting of the 1923-24 board would be held immediately, with President Clamer in the chair.

Approved Nov. 20, 1923.

Respectively submitted,
C. R. Messinger., President.
C. E. Hoyt, *Secretary.*

Minutes of the First Meeting of the 1923-24 Board of Directors, A. F. A., held at the Drake Hotel, Chicago, June 19, 1923, Immediately Following Adjournment of the Retiring Board.

President Clamer in the chair asked the secretary to call the roll. The following officers and directors were present: G. H. Clamer,

president, H. B. Swan, vice president. Directors, L. L. Anthes, A. O. Backert, R. A. Bull, C. B. Connelley, Fred Erb, T. A. Hammond, C. E. Hoyt, W. A. Janssen, C. S. Koch, C. R. Messinger, V. E. Minich, L. W. Olson, and Thos. W. Pangborn.

Absent: Directors Alfred E. Howell and A. B. Root Jr.

The chair announced that he believed all present were familiar with the situation which had resulted in Mr. Swan's finding it necessary to present in writing his resignation as vice president and director.

The chair called on Mr. Swan who said: "I am sure there are many of you here who know of my interest and the goodwill which I bear the Association and the great many friends I have in it. If it were my own personal preference I would gladly continue in the office and in the work of the Association. I assure you it is with a great deal of regret that I feel I must relinquish it. I want to take this occasion to express to my many friends among you all my appreciation of the honor which you did me in electing me to this office."

President Clamer stated that all who had been in close touch with the situation had hoped that Mr. Swan would find it possible to serve, and that his resignation was received with deep regret by all.

It was duly moved that Mr. Swan's resignation as vice president and director be accepted, and that a vote of thanks be extended to him for having so splendidly co-operated with the nominating committee and officers in handling a difficult situation.

The chair formally introduced the new directors; L. L. Anthes, T. S. Hammond, and Thos W. Pangborn.

The chair appointed a nominating committee consisting of A. O. Backert, C. S. Koch, and V. E. Minich, who were asked to retire to consider the selection of a vice president and director to fill the vacancy caused by Mr. Swan's resignation, and nominate four members for the executive committee, a secretary-treasurer, assistant secretary, and manager of exhibits.

The chair introduced the question of the employment of a technical secretary, a matter which had been referred to the executive committee at a meeting of the board on April 29. He stated that there had been much correspondence and that prospective candidates for the office had been interviewed, but that the committee had no definite report or recommendations to make at this time, and that if there were no objections the authority delegated to the executive committee would be passed on to the new executive committee. It was so ordered.

It was the consensus of opinion that the question of a chairman for the molding sand research committee hinged a good deal upon the securing of a technical secretary, and it was moved that the appointment of a chairman for the sand research work be referred to the executive committee. Motion prevailed.

Mr. Messinger moved that President Clamer, Secretary Hoyt, V. E. Minich, and C. B. Connelley, be appointed as official representatives of the Association on the European tour and at the Paris convention. Motion prevailed.

It was announced that H. B. Hanley would prepare a paper for the Paris convention. A communication was received from Mr. Estep advising that it would be desirable to have two papers from the A. F. A.

It was moved that the entire matter of exchange papers be left in the hands of the president of the Association. Motion prevailed.

Mr. Backert, chairman of the nominating committee announced that L. W. Olson was the unanimous choice of the committee for the office of vice president, and moved that the secretary be instructed to cast the unanimous ballot of the board for Mr. Olson. Motion prevailed. The secretary cast the ballot, whereupon the chair declared Mr. Olson elected as vice president and director for the ensuing year.

To fill the vacancy caused by Mr. Olson's elevation to the office of vice president, the nominating committee offered the name of Edward W. Beach, president of the Ferro Machine & Foundry Co. of Cleveland, Ohio. It was moved that the secretary be instructed to cast the unanimous ballot of the board for Mr. Beach as a director to fill the unexpired term of Mr. Olson. Motion prevailed. The secretary cast the ballot whereupon the chair declared Mr. Beach elected a member of the board to succeed Mr. Olson whose term of office would expire in 1925.

Mr. Backert for the nominating committee recommended that the office of secetary and treasurer be combined as provided for in Section 1 of Article III of the by-laws, and offered the name of C. E. Hoyt for the office of secretary-treasurer. It was moved by Mr. Olson and seconded by Mr. Bull that the office of secretary-treasurer be combined and that the president be instructed to cast the unanimous ballot of the board for C. E. Hoyt as secretary-treasurer of the Association. Motion prevailed. President Clamer cast the ballot and declared Mr. Hoyt elected secretary-treasurer for the ensuing year.

Mr. Backert for the committee offered the name of C. E. Hoyt as manager of the department of exhibits and moved his election. Motion seconded by Mr. Bull and carried, the president casting the ballot and declaring Mr. Hoyt duly elected manager of exhibits for the ensuing year.

Mr. Backert for the committee offered the name of Robert E. Kennedy for the office of assistant secretary and moved his election. Motion seconded by Mr. Bull and carried, the secretary casting the ballot for the board, whereupon the chair announced Robert E. Kennedy elected assistant secretary for the ensuing year.

Mr. Backert reported that the nominating committee offered the names of C. R. Messinger, R. A. Bull, V. E. Minich, and Fred Erb as members of the executive committee. It was moved that the secretary be instructed to cast the unanimous ballot of the board for the names presented. Motion prevailed. Secretary Hoyt cast the ballot, whereupon the chair declared C. R. Messinger, R. A. Bull, V. E. Minich, and Fred Erb duly elected, who together with the president, vice president, and secretary-treasurer would constitute the executive committee for the ensuing year.

The chair called for the recommendations of the finance committee on salaries. Mr. Bull for the finance committee recommended that the combined salary of Mr. Hoyt as secretary-treasurer and manager of exhibits be $10,000 a year, $7600.00 to be paid from the funds of the department of exhibits, and $2400.00 to be paid from the funds of the technical department, payable monthly. They recommended further that if a technical secretary is secured a different division of Mr. Hoyt's salary be made by the executive committee if deemed advisable. Mr.

Bull moved that the recommendations of the committee be approved. Motion prevailed.

Mr. Bull continuing his report stated the committee would recommend that Mr. Hoyt's secretary, Miss Reininga be given, effective July 1, an increase in salary from $175.00 to $200.00 a month, $125.00 to be paid from the funds of the department of exhibits, and $75.00 from the funds of the technical department, and moved that the recommendation be adopted. Motion prevailed.

Mr. Bull for the committee moved that on the part time basis in effect during the past year the salary of R. E. Kennedy, assistant secretary, be $150.00 per month, payable from the funds of the technical department. Motion prevailed.

The finance committee recommended that the bonds in the department of exhibits sinking fund be placed in trust, and the following resolution was unanimously adopted:

RESOLVED: That the securities in the sinking fund of the department of exhibits of the Association, now amounting to $18,000 in U. S. government bonds, be placed with the Harris Trust & Savings bank, Chicago, to be held by them as a trust fund, interest coupons to be deposited from time to time to the account of the American Foundrymen's Association, the bonds to be subject to withdrawal at any time upon request signed by the president and treasurer of the American Foundrymen's Association, Inc.

To authorize disbursement of funds the following resolutions were unanimously adopted:

RESOLVED: That G. H. Clamer as president, and C. E. Hoyt as secretary-treasurer, are hereby authorized to sign checks and draw against funds deposited in the Harris Trust & Savings bank, Chicago, Standard Trust & Savings bank, Chicago, and the Central National Bank & Trust Co., Cleveland, Ohio, in the name of the American Foundrymen's Association, Inc.

RESOLVED: That the president and secretary-treasurer be authorized to make necessary arrangements for a special convention fund sufficient to take care of payroll and necessary expenses during the convention and exhibit period, and further that they be authorized to maintain a secretary-manager's petty cash expense fund of $500.00 in the Chicago office to take care of small items of expense, said fund to be reconciled at the end of each month with full statement of expenditures.

Mr. Bull moved that the president be authorized to appoint a committee of three to consider amendments to the by-laws, particularly in regard to membership fees and dues, and report to the board at some future meeting.

To provide for the election of four members for the nominating committee in accordance with Article IX, Section 1 of the by-laws, it was voted that the board name eight members from different sections of the country, representative of the various activities of the Association, and that these names be published in the bulletin and members invited to make additional nominations, and further, should any member secure five or more votes nominating him for election to the nominating com-

mittee, his name should be added to the list named by the board and submitted to the membership with a ballot providing for the election of four members and four alternate members of the 1924 nominating committee.

The board then placed in nominating the following members:

1. A. H. Jameson, Deemer Steel Casting Co., New Castle, Del.
2. Jesse L. Jones, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.
3. James Mitchell, Cleveland Co-operative Stove Co., Cleveland, Ohio.
4. W. B. Greene, Acme-Palmers & DeMooy Fdy. Co., Cleveland, Ohio.
5. J. B. Nordholt, Toledo Steel Casting Co., Toledo, Ohio.
6. Norman Russell, Albert Russell & Sons Co., Newburyport, Mass.
7. S. W. Utley, Detroit Steel Casting Co., Detroit, Mich.
8. Warren G. Jones, W. A. Jones Foundry & Mach. Co., Chicago.

It was moved that a committee be appointed by the president consisting of not more than five nor less than three members, empowered to decide questions of policy in intersociety relations, formulate rules and regulations governing papers presented at annual conventions, exchange papers with other associations, and the publishing of discussions, etc. Motion prevailed.

Mr. Backert offered the suggestion that a solicitor be engaged to call personally on foundrymen for the purpose of securing memberships. Following discussion it was moved that if the services of the right man could be obtained the plan be tried out, the question of engaging the solicitor to be left in the hands of the president, secretary, and Mr. Backert, and that if after a sixty day trial the plan proved satisfactory it should be continued. Motion prevailed.

Mr. Backert announced that Rogers, Brown & Co., Cincinnati, Ohio, indicated that they might wish to give the sum of $500.00 to the Association for research work, and the secretary was instructed to communicate with Rogers, Brown & Co. on this subject.

Mr. Messinger reviewed briefly the work of the committee on standard pattern practice. He explained that the committee had been reorganized with E. S. Carman of the Osborn Manufacturing Co., Cleveland, Ohio, as general chairman, stating that in asking Mr. Carman to take up this work he had assured him of the hearty support of the board of directors.

Mr. Koch moved that the board request Mr. Bull to accept the chairmanship of the finance committee on molding sand research. The motion was carried unanimously, whereupon Mr. Bull stated he would be willing to accept this responsibility for a while at least.

Mr. Thos. W. Pangborn, who, with his brother, had made the original contribution of $2500.00 and made possible the research work, announced

that in the same spirit in which he had made the original contribution he would like to offer an additional $1000.00 on condition that like sums be secured from four other foundry concerns. He added that he was not making this offer as an equipment manufacturer, but as a foundryman.

There being nothing further to come before the board the meeting stood adjourned at 5:25 P. M.

Approved Nov. 20, 1923.

Respectfully submitted,
G. H. CLAMER, *President.*
C. E. HOYT, *Secretary.*

MINUTES OF MEETING OF THE BOARD OF DIRECTORS OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION, HOTEL ASTOR, NEW YORK, NOV. 20, 1923.

Meeting called to order by President Clamer. All directors present with exception of E. W. Beach.

Minutes of last meeting of the 1922-23 board, held in Chicago June 19th, read and approved as read.

Minutes of first meeting of the 1923-24 board, held in Chicago June 19th, read and approved as read.

The chair announced that the first order of business would be the consideration of time and place of the next annual meeting of the Association, Mr. Olson reported a conference between representatives of the A. F. A. and the F. E. M. A. at French Lick, Sept. 24th when it was unanimously decided to recommend to the board of directors that the 1924 meeting be held in the fall, preferably in the month of October.

Following discussion it was moved that the report be accepted and that the chair appoint a sub-committee of three of the convention and exhibits committee, who, together with the president, vice president and secretary should consider invitations received and decide the time and place of the 1924 convention, with the understanding that the meeting should be held in the fall of the year at a place some point west of the city of Cleveland. Motion prevailed.

It was duly moved and seconded that the sum of $250.00 be appropriated for the Institute of Metals Division of the A. I. M. E. from the funds of the department of exhibits. Motion prevailed.

R. A. Bull for the committee on molding sand research reported that Walter M. Saunders of Providence, R. I., had been elected by the executive committee of the A. F. A. as general chairman of the joint committee and that his election had been confirmed by the executive committee of the joint committee at a meeting held in New York on Nov. 3rd.

Mr. Bull read for the approval of the board copy of foreword and statement which had been prepared for printing with the report of the committee on methods of testing.

Mr. Messinger moved that the board approve the statement and authorize the publishing of the report in pamphlet form in addition to publishing it in the bound volume, and that the report be offered for sale at a price to be fixed by the executive committee. Motion prevailed.

The secretary presented a statement showing that the total contributions to the sand research fund together with accumulated interest amounted to $5797.90 and that total expenditures to date had been $5595.87, leaving a balance on hand in the sand research fund of $202.03.

The secretary reported that the executive committee by mail ballot had gone on record in favor of assuring the joint committee on molding sand research that cash to the amount of $5000.00, if needed, would be advanced from the funds of the department of exhibits in support of the work, with the understanding that when the committee's funds permitted, any monies advanced by the Association would be refunded.

It was duly moved and seconded that the board of directors approve the action of the executive committee in the matter of providing funds for sand research. Motion prevailed.

The secretary reported that the executive committee had interviewed and corresponded with a number of prospective candidates for the position of technical secretary but that no one had been engaged for this position. He added that the committee felt that the immediate need for a technical secretary had been lessened somewhat by the securing of Mr. Saunders as chairman of the joint committee on molding sand research.

Mr. Minich moved that the authority for engaging a technical secretary voted the executive committee at the last meeting of the board be continued. Motion prevailed.

The secretary announced that Rogers, Brown & Company of Cincinnati had contributed the sum of $500.00 for research work in cast iron to be conducted under the auspices of the A. F. A. and that this money had been deposited in a special savings fund known as the A. F. A. Rogers, Brown & Co. fund, whereupon the following resolution was unanimously adopted:

WHEREAS, Rogers, Brown & Company of Cincinnati have contributed the sum of $500.00 for research work in cast iron,

THEREFORE, BE IT RESOLVED, That the board of directors of the American Foundrymen's Association accept this gift for the purpose for which it was intended, and on behalf of the membership at large extend to Rogers, Brown & Company sincere thanks for their contribution to research.

R. A. Bull, chairman of the committee, authorized at the June meeting of the board to consider revision of the by-laws, reported that the committee had no recommendations to make at this time.

It was moved that the committee be continued and instructed to submit a report at the next meeting of the board. Motion prevailed.

The secretary in submitting a report on membership stated that the book membership of the Association on Jan. 1, 1923, was 1456; that from Jan. 1st to Nov. 15th 214 new members were elected; that during that period 73 delinquents had been dropped, 47 resignations received, two removed by death, total of 122; making the book membership Nov. 15, 1923, 1548, a net gain of 92.

The question of a membership committee was discussed and the president and secretary were instructed to consider a plan of forming a large committee with members in each foundry center of the country.

Reporting for the cost committee the secretary read copy of minutes of a meeting held on Nov. 9th, recommending that a systematic publicity campaign be inaugurated calling the attention of foundrymen to the importance of their consideration of cost finding. A further recommendation of the committee was that the board consider the engaging of a man at a reasonable retainer to collect data, illustrations, object lessons, etc., for a series of letters or bulletins.

It was moved that the report be accepted and the board go on record as heartily endorsing the plan for an educational campaign but as not being in favor of engaging the services of a man to conduct it, believing that sufficient contributions of value could be secured from members interested in this work, and authorizing the expense of publishing and mailing educational bulletins. Motion prevailed.

The board then took under consideration the seven fundamental principles of cost finding, which had been adopted by the cost committee and reported at the meeting of the board on June 19th. Following the reading of each principle by the secretary the chair called for remarks.

Mr. Messinger moved that the board approved of the fundamental principles as adopted and recommended by the cost committee. Motion prevailed.

The secretary reporting for the board of awards stated that in accordance with instructions of the board of directors at the June meeting, mahogany clocks had been sent to Hugh A. Mackie and Charles M. Parsons of the Homestake Mining Company, Lead, S. Dak., each bearing a silver plate with the inscription on one "Presented by American Foundrymen's Association to Charles M. Parsons, Joint Winner S. Obermayer Company Prize, 1923," and on the other a similar inscription for Mr. Mackie.

The secretary reported further that the special committee consisting of C. R. Messinger, R. A. Bull and C. E. Hoyt, appointed with authority to engage an artist, select designs and procure the necessary dies for making four medals, had engaged the services of Frederick Hibbard, a sculptor of Chicago, who was working on designs.

He reported further that in accordance with instructions of the board all bonds representing the principals of the award funds had been deposited with the Harris Trust and Savings bank as custodians, subject to withdrawal only on the written order of the president and secretary-treasurer accompanied by a certified copy of a resolution of the board of directors authorizing said withdrawal, interest coupons to be clipped when due and deposited to the credit of the American Foundrymen's Association award interest fund, the interest fund to be available for defraying expenses of making awards upon the joint signatures of the president and secretary-treasurer of the Association.

The secretary announced that the $18,000.00 in Liberty Bonds in the reserve fund of the department of exhibits had been deposited with the Harris Trust and Savings bank as custodians, interest coupons to be deposited from time to time to the account of the Association and when this fund amounted to $500.00, additional bonds of that denomination would be purchased, the bonds in this fund to be subject to withdrawal at any time upon request signed by the president and secretary-treasurer of the Association.

The secretary submitted copy of rules and regulations drafted by the papers committee governing contributions for the technical sessions and asked their approval.

Mr. Connelley moved that the rules and regulations as submitted be adopted and copies ordered printed. Motion prevailed.

Mr. Olson submitted a communication from the department of the interior, bureau of mines, Ithaca, N. Y., on the possibilities in the use of oxygenated air in metallurgical work, especially in relation to the production of pig iron, for which the approval of the Association was asked.

Mr. Messinger moved that the secretary write the bureau of mines that it was the sense of the board of directors of the American Foundrymen's Association that if their experiments were carried on and brought to a successful conclusion, it would be of real value to the foundry industry. Motion prevailed.

The secretary read a letter from W. H. Stewart, director, department of commerce, bureau of the census, requesting co-operation in the securing of statistics for the census of manufactures for the year 1923.

It was moved that the Association co-operate with the bureau to the extent of urging the members to co-operate by sending in their reports promptly. Motion prevailed.

The secretary called attention to the fact that owing to the change from spring to fall convention it would be advisable to include in Bound Volume 31 all proceedings, minutes of board meetings, auditor's reports, etc., for the year ending Dec. 31, 1923. It was so ordered.

The board approved of the proposal that beginning January, 1924, the Association bulletin be published as a quarterly and recommended that a monthly service letter be inaugurated, in which should be incorporated by title and author only a list of all foundry articles appearing in current publications.

It was moved that at the 1924 convention admission to the exhibits be by badges given to members and guests as they registered, and that a registration fee of $1.00 be charged, instead of free registration and charge for admission as in the past, and that a single admission charge of fifty cents be made to everyone who entered the exhibits without registering. Motion prevailed.

The secretary submitted the following resolution, which was unanimously approved:

RESOLVED, That the board of directors of the American Foundrymen's Association hereby approved of the disbursement of the Association's funds by checks bearing the signature of vice president L. W. Olson and issued during President Clamer's absence from the country.

President Clamer, Director Minich, and Secretary Hoyt gave reports of the International convention at Paris, reciting receptions tendered the delegation at various points in England, France and Belgium.

Mr. Hammond moved that the chair appoint a committee to prepare resolutions of appreciation to be forwarded to the Institute of British Foundrymen, to the London, Sheffield, Lancashire, Manchester, Birmingham, and Coventry branches of the I. B. F., to the Iron & Steel Institute of England, to the Association Technique de Fonderie de France, and to the Association Technique de Fonderie de Liege Belgium, and that greetings from the board be cabled forthwith to Messrs. Oliver Stubbs, president of the I. B. F. and H. Cole Estep. Motion prevailed.

The following resolution was unanimously adopted:

WHEREAS, Mr. H. Cole Estep, as the European representative and chairman of the A. F. A. committee on international relations, has rendered exceptional services during the past year.

THEREFORE, BE IT RESOLVED: That the board of directors of the American Foundrymen's Association express sincere appreciation of the splendid manner in which Mr. Estep has represented the Association and commend him for excellent work in connection with the International Convention of Foundrymen at Paris, Sept. 12 to 15, 1923.

There being no further business, on motion, the meeting adjourned.

Respectfully submitted,

G. H. CLAMER, *President.*

C. E. HOYT, *Secretary.*

Annual Report of Manager of Exhibits

The following is submitted as a report for the seventeenth annual exhibit of foundry equipment and supplies held in conjunction with the annual meetings of the American Foundrymen's association, which was the seventh annual exhibit held under the auspices of the American Foundrymen's association. This exhibit was held in the Public Auditorium, Cleveland, Saturday, April 28, to Thursday, May 3, 1923. The exhibit was not open to the public on Sunday, April 29.

Floor plans accompanied by space application blanks were mailed out on Jan. 13 to all previous exhibitors. It was our plan to mail at a later date information and application blanks to our prospect list but the responses and demands for space from those who received the first announcement indicated that all available space would be required by previous exhibitors.

A meeting of the convention and Exhibits Committee was called at Cleveland, Jan. 24, at which time it was agreed not to solicit any new exhibits. It was further agreed not to provide for the usual exhibits of machine tools until after the exhibits of foundry equipment and supplies had been provided for.

Even with this curtailment of activity the demand for space was such that it was found necessary to either secure additional space or appeal to exhibitors to cut down their requirements. Investigation proved that no other space was available and when the exhibitors were appealed to, they voluntarily reduced their requests for space on an average of 20 per cent and the manager desires at this time to express his appreciation of the splendid co-operation of the exhibitors when asked to assist in solving this unusual condition. An idea as to the extent to which exhibits were curtailed will be seen in a comparison of the 1919 and 1923 exhibits. In each instance there were 214 exhibitors. At Philadelphia in 1919 they occupied 60,400 square feet of space. At Cleveland the same number were crowded into 47,055 square feet.

Of the 214 exhibitors, 100 used electric power. Aside from socket connections for lights, signs and models, there was

a total of 139 motors connected with a total rated horsepower of 677. There were also the usual number of users of compressed air and three air compressors with a total capacity in excess of 1200 cubic feet per minute were installed to provide this service.

The plan of opening the exhibits on Saturday preceding the opening of the annual convention of the American Foundrymen's Association on Monday was decidedly helpful so far as the management was concerned and was generally acceptable to the exhibitors. It would be our recommendation that the same plan be followed another year.

A complete financial statement for the department of exhibits will be found in the auditor's report. Attention is called to the fact that this audit covers a period of 16 months, Sept. 1, 1922, to Dec. 31, 1923.

For comparison we give the number of exhibitors, amount of space, and the average square feet per exhibitor for the seven exhibits held under the auspices of the association.

Year	City	Exhibitors	Total Space sq. ft.	Average per exhibitor sq. ft.
1916	Cleveland	146	37,930	260
1917	Boston	155	43,674	281
1918	Milwaukee	198	42,474	214
1919	Philadelphia	214	60,400	282
1920	Columbus	241	76,600	317
1922	Rochester	178	46,787	262
1923	Cleveland	214	47,055	219

Average number of exhibitors for the seven years—192+.

Average space used per exhibitor—262+ square feet.

Although the Cleveland Auditorium is one of the most beautiful buildings in the country, it was possible through the splendid co-operation of Mr. Lincoln Dickey, Manager, for us to conduct the usual operating exhibit. To Mr. Dickey and to Mr. A. J. Kennedy, Secretary of the Convention Board of the Cleveland Chamber of Commerce, we express sincere appreciation for their courteous and helpful assistance at all times.

Respectfully submitted,

C. E. Hoyt, *Manager, Department of Exhibits.*

Annual Report of the Secretary-Treasurer

To the President and Members of the American Foundrymen's Association, Inc.

Gentlemen:

The secretary-treasurer's report contained in bound volume No. 30 was for the fiscal year ending Dec. 31, 1921. This report contains membership statistics for the years ending Dec. 31, 1922, and December 31, 1923.

When, at the November meeting of the board it was voted to hold the next convention in the fall of 1924, it was decided to defer printing bound volume No. 31 until a complete report of all activities of the Association for the calendar year 1923 could be included; hence the report for two full years in this volume. This volume also contains auditors' reports for both years. Hereafter the reports will be for one calendar year which is also the fiscal year.

Membership

On Jan. 1, 1922 we had a book membership of 1570, with 101 in arrears for 1921 dues, 89 of whom were eventually dropped, reducing the total membership to 1481. During the year two were removed by death, and 115 resigned, still further reducing the membership to 1364. During 1922, 92 new members were elected as against 32 for the previous year, making a total membership of 1456 for the year ending Dec. 31, 1922.

Beginning the year 1923 with a book membership of 1456, 78 were in arrears for 1922 dues and were dropped, 56 resigned and two were removed by death, making a total of 136, which would have reduced the membership to 1320 but for the election of new members of whom there were 240 during the year, making the total book membership for the year ending Dec. 31, 1923, 1560, a net increase of 104 for the year. All but 42 are fully paid up and in good standing.

It is interesting to note that of the total of 338 who resigned or were dropped because of being in arrears, during the years 1922 and 1923, 251 of them were elected to membership during the peak years of 1919 and 1920, when a total of 669 new members were secured. A very large percentage of the loss was due to foundries going out of business following the depression of 1921.

Finances

The auditor's report for 1922, for the technical department, printed in this volume, shows that we started the year with a balance of $706.06. In this figure the auditor included the Cleveland Research Fund of $410.81. Our actual cash balance was only $295.25.

On Jan. 1, 1923, we show a cash balance of $1458.59, and the report shows that we closed the year on Dec. 31, with a cash balance of $3721.78. In the 1923 report we show for the first time, a consolidated balance sheet for the technical and exhibit departments, giving assets and liabilities of both departments.

Cleveland Research Fund

During 1923 the Cleveland Research Fund was increased by the contribution of $660.87 which was the balance left in the entertainment fund following the Cleveland convention. The original contribution to this fund, amounting to $337.11, was contributed by the Cleveland entertainment committee following the 1916 convention. These two contributions including interest totaled on Dec. 31, 1923, $1118.72.

Rogers Brown Fund

On Aug. 17, 1923, we received a contribution of $500 from Rogers, Brown & Co., Cincinnati. The donors desire that this fund be used for research work in connection with cast iron.

Contribution to Molding Sand Research Work

On June 6, 1923, a contribution of $1000 to the molding sand research fund was received from the American Foundry Equipment Co. of New York City.

Awards

Following consideration by the board as to the best method of handling the awards funds which had been so generously placed at the disposal of the association, it was voted at a meeting on Oct. 3, 1922, to place the matter in the hands of a permanent board of awards, consisting of the seven last living past presidents, with the junior past president chairman of the board.

This board was immediately organized and following conferences with the donors conditions of the gifts were agreed upon and incorporated in deeds of gift which were drawn up in legal form and signed by the donors or their authorized representatives, and by the president and secretary for the association, during the Cleveland convention, and announcement of the consummation of this somewhat difficult task was made at the annual banquet.

The conditions of agreement, which are alike for the J. S. Seaman, John A. Penton, W. H. McFadden, and J. H. Whiting funds, are as follows:

"IN CONSIDERATION of the fact that the donor is interested in promoting the progress and development of the arts and sciences practiced and applied by manufacturers in the production of metal castings, and in further consideration of his desire to encourage and stimulate meritorious effort in the industry of making metal castings, he does by these presents give, grant, set and deliver over and unto the association, its successors or assigns, forever, the sum of $5000 to be known as the (name of donor) fund, upon the following terms and conditions:

"The board of awards of the said association shall control the disposition of the said fund, together with the income therefrom, subject to the terms and conditions herein set forth. The board of awards shall invest, and in their discretion reinvest the said fund in securities of the kind and quality designated by the laws of the state of Illinois for the investment of trust funds. In the event that the board of awards shall cease to perform its duty hereunder, or shall cease to function, then the

disposition of the said fund shall be governed by the directors of the association instead of the board of awards, but under the same terms and conditions as are herein provided.

"It is the desire of the donor that an award, prize, medal or scholarship shall be conferred each year, if feasible, upon some person who shall by his individual effort have achieved very noteworthy results toward the attainment of those objects for which the association was formed. The board of awards, or if they shall have ceased to act, then the board of directors, shall decide when an achievement is worthy of recognition.

"The name of the donor shall be used in connection with the use of the award funds.

"If the amount of income derived from said and similar sums of money shall exceed the amounts used for prizes or awards, then such surplus income shall be used for any or all of the following purposes:

1. To defray expenses in securing dies for medals, engrossed certificates and for similar purposes, in connection with making awards;

2. To conduct research work which will promote the objects of the association;

3. To engage the services of such persons as may be selected by the board of awards to expound technical subjects in which the association is interested, at its annual convention.

"Should the American Foundrymen's association be dissolved, the said gift of $5,000 or the securities in which the said sum has been invested, together with any unexpended income therefrom, shall revert as a resulting trust to the donor, his heirs, executors, administrators, or assigns.

"In witness whereof the donor has hereunto set his hand and seal, and the American Foundrymen's association has caused this instrument to be executed in its corporate name, and in its behalf by its president, and its corporate seal to be hereunto affixed, and the same to be attested by the signature of its secretary at Chicago, Illinois."

The following resolutions were adopted by the board of directors in acknowledgement of the gifts of awards, and illuminated copies were bound in leather cases and presented to each donor:

The American Foundrymen's association memorializes the appreciation of its members for the munificence of—

"JOSEPH S. SEAMAN"

in his gift which establishes the

"J. S. SEAMAN FUND."

This generosity to those engaged in the industry in which he was so notably successful, reminds all those who knew him of his kindliness. The dominant note of his character was love and cheerfulness abounding with industry. Of this spirit we sincerely hope each recipient from the J. S. Seaman Fund may partake, by emulating his life and character. By resolution of the board of directors this expression is conveyed to the family of Mr. Seaman with their love for and affectionate memory of "Daddy."

The American Foundrymen's association has been the growth of an idea. It recognizes its indebtedness to

JOHN A. PENTON

for conceptions which in the incipiency of its existence nourished and strengthened it. By establishing the

JOHN A. PENTON FUND

he has opened up vistas of future progress which will realize his ambition for the prosperity of the industry to whose advancement he has devoted a life uniquely successful. To Mr. Penton this association feels profoundly grateful, and the officers and board of directors desire that he be reminded by these presents, not only of their appreciation, but of the gratitude of those following us, however remotely in the future, encouraged and sustained by ambitions which he has incited.

The American Foundrymen's association hereby signalizes its appreciation of the gift of

WILLIAM H. McFADDEN

which establishes the

W. H. McFADDEN FUND

This fund incites courage and enterprise in new achievements in the industry we represent. These are the outstanding characteristics of Mr. McFadden, along with his genial humor, his resourcefulness at all times, and his power to achieve. Those who know Mr. McFadden will recount to others these traits.

His example will inspire others, as it has inspired the officers and members of this board, by whose action this testimony of appreciation is presented to him with assurances of the cumulative good he has done us, and those after us, who will carry on the objects of our association.

The American Foundrymen's Association to

J. H. WHITING

Greeting

Whereas, Mr. J. H. Whiting has presented to this association a sum sufficient for the endowment "in perpetuo" of

THE J. H. WHITING FUND

and by this gift emphasizes the importance of, and evinces his interest in, new achievements in the foundry industry, and the building of business on an ascending scale of scientific exactness, thus creating new sources and forces for world betterment.

It is Resolved, by the officers and board of directors of this association, that Mr. Whiting be tendered an expression, in enduring form, of our appreciation of his generous act and by these presents we do assure him of the gratitude of this present board, and those who shall follow after us.

First Awards to Be Made in 1924

At the meeting of the board of directors, June 19, 1923, the board of awards recommended that at the 1924 convention a John A. Penton medal of the American Foundrymen's association be awarded to Enrique Touceda in recognition of the

contributions he has made to the malleable casting industry; and that a J. H. Whiting medal of the American Foundrymen's association be given to John Howe Hall in recognition of his contributions to the steel casting industry.

It was further voted that if at the 1924 convention a paper of outstanding merit be presented, it shall be recognized by conferring upon the author of the paper, a W. H. McFadden medal of the American Foundrymen's association, presentation to be made at the 1925 convention.

These recommendations were unanimously approved by the board of directors.

Procuring of Medals

A special committee was appointed and given full authority to engage a sculptor to design medals and have made the necessary dies for striking them.

Molding Sand Research

No work yet undertaken by the American Foundrymen's association is more vital or promises larger economic results than that being conducted by the joint committee of 60 members on molding sand research.

Under the direction of Dr. Ries extensive geological researches have been conducted, and during 1923 nearly 700 samples of sand were collected in 14 different states. They are being tested in the laboratories of the United States bureau of standards, Cornell university, and the University of Illinois. Methods for testing submitted at the Cleveland convention have been modified and improved by the members of the committee on tests. Their complete report appears in this volume.

The association and the foundry industry is deeply indebted to many members of the committee, but to none more than to Major R. A. Bull, who served as chairman of the committee from the date of organization, October, 1921, until he found it necessary to ask to be relieved of the chairmanship in September, 1923, when Walter M. Saunders of Providence, R. I., was appointed to succeed him.

International Congress of Foundrymen.

An important event in the foundry world was the holding of the first International Congress of Foundrymen at Paris, Sept. 12 to 15. The Association Technique de Fonderie of France were hosts to the foundrymen of eight nationalities. The invitation to participate was officially accepted by our association, and a delegation of 29 members headed by President G. H. Clamer attended. Enroute the delegation were guests of the Institute of British Foundrymen at London, Sheffield, Manchester, Birmingham, and Conventry. The wonderful hospitality of our English cousins during the 17-day sojourn in England was greatly appreciated.

The Paris Congress was voted a success and plans were discussed for holding a second International Congress of Foundrymen, which it was suggested might be held in the United States in 1926 or 1927.

Following the adjournment of the Congress the American Foundrymen's association delegation were guests of the Association Technique de Fonderie of Nancy, France, and the Association de Fonderie of Belgium at Liege.

At the meeting of the board of directors held in November the sending of illuminated resolutions of appreciation to all the associations who were hosts to the American Foundrymen's association delegation, was authorized.

The activities of the association are further reviewed in the annual address of President Messinger, in the minutes of the board of directors, and in committee reports, which appear in this volume.

For the aid and support given him by President C. R. Messinger, Vice President G. H. Clamer, Assistant Secretary R. E. Kennedy, the board of directors, committee members who by their efforts have contributed in a large way to the success of the association, and all his assistants, the secretary-treasurer extends his warmest appreciation and sincere thanks.

Respectfully submitted,

C. E. Hoyt, *Secretary-Treasurer.*

Auditors' Financial Report of Technical Department

Chicago, Jan. 11, 1923.

Mr. C. R. Messinger, President,
American Foundrymen's Association, Inc.,
Chicago, Ill.

Dear Sir:

In accordance with instructions received from Mr. C. E. Hoyt, secretary-treasurer, we have audited the books of the technical department of the American Foundrymen's Association, Inc., for the year ended Dec. 31, 1922. We now submit our report, accompanied by the following statements:

Statement of Cash Receipts and Disbursements for the year ended December 31, 1922	Exhibit A
Securities	Exhibit B
Trial Balance of the General Ledger after closing, December 31, 1922	Exhibit C

Cash Receipts and Disbursements

The statement of cash receipts and disbursements, Exhibit A, shows the cash receipts and payments for the year, and the cash balances in banks at Dec. 31, 1922.

The cash balances as at Dec. 31, 1922 were verified by certificates obtained from the various depositaries of the Association, and the reconciliation thereof with cash records.

We examined all cancelled checks and saw that they were properly entered in the cash book. Approved vouchers on file, supporting disbursements for the year, were all examined.

We saw that all cash receipts recorded in the cash book had been duly deposited in bank and made a test check of receipts from membership dues, examining approximately 10 per cent of the membership cards and tracing the payment of dues recorded thereon to the cash receipts. Unpaid membership dues at Dec. 31, 1922 amounted to $1158. We verified the interest received from Liberty Bonds and other securities.

Securities

Bonds aggregating $21,000, par value, constituting the several award funds were inspected by us at the safety deposit vault of the Harris Trust and Savings bank. These securities are listed in detail on Exhibit B.

Special Funds

We verified the cash transactions affecting the various special funds. The balance of the National Engineering-Simpson Fund of $832.41 at Dec. 31, 1922 was evidenced by a certificate furnished by the bank. The Pangborn Fund was closed out at Dec. 31, 1922. The transactions affecting these funds are shown in the following summary:

	Funds	
	Simpson	Pangborn
Balance, December 31, 1921, per Audit Report	$1,025.15	$ 748.97
Interest Earned	30.97	22.62
	$1,056.12	$ 771.59

Less: Disbursements for Research Work	223.71	771.59
Balance, December 31, 1922 Exhibit C .....$ 832.41	$	

The transactions affecting the various Award Funds and the resulting balances at Dec. 31, 1922 have been summarized as follows:

	Seaman	Whiting	McFadden	Obermayer	Penton
Balance, December 31, 1921 — per. Audit Report	$5,212.50	$5,212.50	$5,212.50	$1,040.63	
Bonds received in 1922					$5,000.00
Interest earned	212.50	212.50	212.50	43.61	150.00
	$5,425.00	$5,425.00	$5,425.00	$1,084.24	$5,150.00
Disbursement for prize				40.00	
Balance, December 31, 1922—per Exhibit C	$5,425.00	$5,425.00	$5,425.00	$1,044.24	$5,150.00

Trial Balance as at December 31, 1922

In Exhibit C we present the trial balance of the general ledger after closing on Dec. 31, 1922. We have verified all balances on deposit in banks and the securities shown on this trial balance. There has been no change in the furniture and fixtures account during the year and no provision has been made for depreciation thereon. The inventory, which we have not verified, consisted of books and other printed matter on hand, which, we understand, was priced at cost. The item award fund surplus, $20.80 represents the interest on the savings account of the award funds.

* * * * *

We are pleased to state that we found the records of the secretary's office in good order and we wish to acknowledge the assistance given our representative by the secretary and the employes of his office during the course of the audit.

Respectfully submitted,
JOHN K. LAIRD & COMPANY,
Certified Public Accountants.

Exhibit A

AMERICAN FOUNDRYMEN'S ASSOCIATION, INC

Technical Department

Statement of Cash Receipts and Disbursements
For the year ended December 31, 1922

Cash Balance, December 31, 1921— per Audit Report		$ 706.06
Receipts		
Membership Dues	$16,994.06	
Miscellaneous Publications, etc.	452.91	
Exhibit Department— Donation .....$ 3,000.00		

Repayment of 1921 Loan	500.00	3,500.00	
Interest—			
Bank .....$	94.01		
Securities	333.63	427.64	
Total Receipts		$21,374.61	
Disbursements			
Salaries .....$	6,650.00		
Publications	4,245.41		
Stenographic and Clerical	2,083.10		
Committee Meeting Expense	1,838.65		
Printing and Stationery	1,173.64		
Convention Expense	996.79		
Postage	775.40		
Rent	516.00		
Traveling Expense	448.97		
Telephone and Telegrams	104.18		
Auditing	100.00		
Office Expense	97.02		
Dues—Other Associations	67.00		
Discount and Exchange	60.05		
General Expense	26.72		
	$19,182.93		
Amount transferred to Award Funds—Interest received	1,011.76		
Total Disbursements		20,194.69	
Excess of Receipts over Disbursements for year ended Dec. 31, 1922			1,179.92
Cash Balance, Dec. 31, 1922—Exhibit C			$1,885.98
Represented by:			
Cash in Banks—			
Harris Trust and Savings Bank		$ 1,458.59	
Central National Bank		427.39	
		$ 1,885.98	

Exhibit B.

AMERICAN FOUNDRYMEN'S ASSOCIATION, INC.

Technical Department

Securities

	Par Value	Rate of Interest
Whiting Award Fund		
Second Converted Liberty Bonds .....$	5,000.00	4¼%
McFadden Award Fund		
Second Converted Liberty Bonds .....$	5,000.00	4¼%
Seaman Award Fund		
Fourth Liberty Bonds .....$	5,000.00	4¼%
Obermayer Award Fund		
First Liberty Bonds .....$	200.00	4¼%

Fourth Liberty Bonds	300.00	4¼%
Second Converted Liberty Bonds	450.00	4¼%
Victory Bonds	50.00	4¼%
	$ 1,000.00	
Penton Award Fund		
The Chester-Twelfth Company	$ 5,000.00	6 %
Total	$ 21,000.00	

Exhibit C

AMERICAN FOUNDRYMEN'S ASSOCIATION, INC.

Technical Department

Trial Balance of General Ledger

After closing, December 31, 1922

	Debit	Credit
Harris Trust and Savings Bank	$ 1,458.59	
Harris Trust and Savings Bank—Simpson Fund	832.41	
Central National Bank, Cleveland, Ohio	427.39	
Inventory of Publications, etc.	632.00	
Furniture and Fixtures	609.00	
National Engineering—Simpson Fund		832.41
Surplus Account		3,126.98
Harris Trust and Savings Bank—Award Funds	1,490.04	
Securities	21,000.00	
McFadden Award Fund		5,425.00
Seaman Award Fund		5,425.00
Whiting Award Fund		5,425.00
Penton Award Fund		5,150.00
Obermayer Award Fund		1,044.24
Award Funds Surplus		20.80
	$26,449.43	$26,449.43

Auditor's Report for Department of Exhibits

Chicago, Jan. 12, 1924

Mr. G. H. Clamer, President,
American Foundrymen's Association, Inc.,
Chicago,

Dear Sirs:

In accordance with instruction, we have audited the books of the technical department of the American Foundrymen's Association for the year ended Dec. 31, 1923. We have also audited the books of the department of exhibits for the period of sixteen months from Sept. 1, 1922 to Dec. 31, 1923. We now submit our report thereon, together with the following statements:

Consolidated Balance Sheet as at December 31, 1923 Technical and Exhibits Departments	Exhibit A
Technical Department	
Statement of Income and Expenses for the year ended December 31, 1923—General Fund	Exhibit B
Statement of Cash Receipts and Disbursements for the year ended December 31, 1923	Exhibit C
Statement of Surplus as at December 31, 1923	Exhibit D
Securities	Schedule I
Department of Exhibits	
Statement of Income and Expense for the period from September 1, 1922 to December 31, 1923 (General Fund)	Exhibit E
Statement of Cash Receipts and Disbursements for the period from September 1, 1922 to December 31, 1923	Exhibit F
Statement of Surplus as at December 31, 1923	Exhibit G

Balance Sheet

In the preparation of the Consolidated Balance Sheet, Exhibit A, we have combined the assets and the liabilities of the technical and exhibits departments for the purpose of showing in a single statement the financial condition of the American Foundrymen's Association as at Dec. 31, 1923.

The cash balances as at Dec. 31, 1923 were verified by certificates obtained from the various depositaries and a reconciliation thereof with your cash records.

The accounts receivable of the technical department represent principally unpaid dues for the year 1923. The accounts receivable of the department of exhibits consist of balances due for space and services.

We did not verify the inventories amounting to $672.15 which consist of books and printed matter and are priced at cost.

Furniture and fixtures represent the book value of these assets, less depreciation which we have written off at the rate of 10 per cent per annum for four years.

Investment securities, which are held by the Harris Trust and Saving bank, Chicago, for safe-keeping, were verified by correspondence with the bank. The details of bonds owned by the technical department, aggregating $21,000 par value, are shown on Schedule I. The securities belonging to the department of exhibits consist of second converted U. S. Liberty Loan Bonds, par value $18,000, which are carried on the books at cost of $16,504.67.

The details of the surplus accounts of the technical and exhibits departments are shown on Exhibits D and G, respectively.

The transactions affecting the various award funds and the resulting balances at Dec. 31, 1923 are summarized in the following table:

Special Funds	Balance Dec. 31, 1922	1923 Receipts	1923 Disbursements	Balance Dec. 31, 1923
McFadden	$ 5,425.00	$ 212.50	$	$ 5,637.50
Obermayer	1,044.24	41.55	66.00	1,019.79
Penton	5,150.00	300.00		5,450.00
Seamen	5,425.00	212.50		5,637.50
Whiting	5,425.00	212.50		5,637.50
Simpson	832.41	52.14	857.55	
Rogers Brown		505.00		505.00
Cleveland Reserve	427.39	691.33		1,118.72
Award Fund Surplus or *Deficit*	20.80	58.50	85.00	*5.70*
	$23,749.84	$2,259.02	$1,008.55	$25,000.31

The balance on deposit in the Central National bank, Cleveland, $1,118.72, representing donations from the Cleveland entertainment committee has been transferred from the general fund and set aside as a special fund.

During the year, one new fund was created, viz., the Rogers Brown fund, $500 and the Simpson fund was closed by transfer of the balance to the general fund for sand research purposes.

By authority of the directors, a reserve fund was established in the department of exhibits by depositing Liberty Bonds, aggregating $18,000, par value, in trust with the Harris Trust and Savings bank, subject to withdrawal at any time upon request signed by the president and treasurer of the Association.

Technical Division

The revenues and expenses of this department for the year ended Dec. 31, 1923 are presented on the statement of Income and Expenses, Exhibit B. The total income for the year amounted to $24,158.73 while the expenses were $21,320.40. The excess of income over expenses, amounting to $2,838.33 has been carried to the general fund surplus account.

A classified statement of the cash receipts and disbursements of this department for the year ended Dec. 31, 1923 is shown on Exhibit C.

Department of Exhibits

Exhibit E shows the income and expenses of this department applicable to the sixteen months' period from Sept. 1, 1922 to Dec. 31, 1923. The

excess of income over expenses for this period was $5,741.03, which has been credited to surplus account. A statement of the cash receipts and disbursements for the same period is submitted on Exhibit F.

General Comments

In addition to those matters specifically referred to in the foregoing report, we may state that we examined all cancelled checks issued by both departments and saw that they were properly entered in the cash books. Approved vouchers on file supporting disbursements for the year were inspected. We saw that all cash receipts recorded in the cash books had been duly deposited in banks.

We are pleased to report that we found the books and records of the secretary's office in good order and we take this opportunity to acknowledge the facilities afforded our representatives for the purposes of this audit.

Respectfully submitted,
JOHN K. LAIRD & COMPANY,
Certified Public Accountants.

Exhibit X

Exhibit A

AMERICAN FOUNDRYMEN'S ASSOCIATION

Consolidated Balance Sheet as at December 31, 1923

Technical and Exhibits Departments

ASSETS

	Technical Department	Department of Exhibits	Total
General Fund			
General Fund			
Cash in Banks	$3,721.78	$ 1,998.91	$ 5,720.69
Accounts Receivable	577.94	489.57	1,067.51
Inventories	672.15		672.15
Furniture and Fixtures, less Reserve for Depreciation	377.35	510.05	887.40
Total General Fund Assets	$ 5,349.22	$ 2,998.53	$ 8,347.75
Special Funds			
Cash in Banks	$ 4,000.31	$ 428.17	$ 4,428.48
Investment Securities	21,000.00	16,504.67	37,504.67
Total Special Fund Assets	$25,000.31	$16.932.84	$41,933.15
Total Assets	$30,349.53	$19,931.37	$50,280.90

LIABILITIES AND NET WORTH

General Fund			
Surplus	$ 5,349.22	$ 2,998.53	$ 8,347.75
Special Funds			
McFadden Award Fund	$ 5,637.50		
Seaman Award Fund	5,637.50		
Whiting Award Fund	5,637.50		
Penton Award Fund	5,450.00		
Obermayer Award Fund	1,019.79		
Rogers Brown Fund	505.00		
Cleveland Reserve Fund	1,118.72		
Award Fund Deficit	5.70		
Reserve Fund		16,932.84	
Total Special Funds	$25,000.31	$16,932.84	$41,933.15
	$30,349.53	$19,931.37	$50,280.90

Exhibit C

AMERICAN FOUNDRYMEN'S ASSOCIATION

Technical Department

Statement of Cash Receipts and Disbursements

For the year ending December 31, 1923

Bank Balance as at December 31, 1922—		
Harris Trust and Savings Bank		$ 1,458.59
Receipts		
Membership Dues and Entrance Fees	$20,051.36	

Miscellaneous Publications, etc.	492.78	
Donations, Department of Exhibits	3,000.00	
Donations to Sand Research	2,782.55	
Bank Interest	138.59	
Total Receipts		26,465.28
		$27,923.87
Disbursements		
Committee Meeting Expense	$ 2,595.59	
Convention Expenses	1,032.70	
Discount and Exchange	63.72	
Dues in other Associations	25.00	
Purchase of furniture	19.95	
Office Expense	52.44	
Postage	1,252.50	
Printing and Stationery	1,134.76	
Traveling Expenses	435.90	
Auditing Expenses	115.00	
Publication	8,051.44	
Rent	516.00	
Research Expenses	2,884.49	
Salaries, Secretary and Assistants	4,350.00	
Stenographers and Clerks	1,600.44	
Telegrams and Telephone	72.16	
Total Disbursements		24,202.09
Cash Balance, Dec. 31, 1923—Exhibit A		$ 3,721.78

Exhibit D.

AMERICAN FOUNDRYMEN'S ASSOCIATION

Technical Department
Statement of Surplus
As at December 31, 1923

Balance, December 31, 1922, per Audit Report		$3,126.98
Adjustments affecting prior years:		
Deduct: Depreciation written off on Furniture and Fixtures, 1920-1922	$188.70	
Cleveland Reserve Fund, December 31, 1922	427.39	616.99
Adjusted Surplus, December 31, 1922		$2,510.89
Excess of Income over Expenses for the year ended December 31, 1923—Exhibit B		2,838.33
Balance, December 31, 1923—Exhibit A		$5,349.22

Schedule I

AMERICAN FOUNDRYMEN'S ASSOCIATION

Technical Department
Securities

	Par Value	Rate of Interest
McFadden Award Fund		
Second Converted Liberty Bonds	$ 5,000.00	4¼%
Seaman Award Fund		
Fourth Liberty Loan Bonds	5,000.00	4¼%
Whiting Award Fund		
Second Converted Liberty Bonds	5,000.00	4¼%
Obermayer Award Fund		
Second Converted Liberty Bonds	1,000.00	4¼%
Penton Award Fund		
The Chester-Twelfth Co. "B"	5,000.00	6 %
Total	$21,000.00	

Exhibit F

AMERICAN FOUNDRYMEN'S ASSOCIATION

Department of Exhibits
Statement of Cash Receipts and Disbursements
for the period from September 1, 1922 to December 31, 1923

Cash Balance as at August 31, 1922:		
Standard Trust and Savings Bank	$ 7,236.17	
Petty Cash	200.00	$ 7,436.17
Receipts		
Rental Space	$36,540.00	
Permits	5,475.00	
Power	4,933.24	
Gate Receipts	1,589.66	
Accounts Receivable	1,007.30	
Carpenter Work—Booths	692.48	
Exhibitors Registration	666.00	
Interest, U. S. Liberty Bonds	488.75	
Interest, Bank Deposits	187.46	
Interest, Accounts Receivable	5.13	
Sale of Typewriters	55.00	
Refund—Advertising	6.25	
Refund—Insurance	3.54	
Total Cash Receipts		51,649.81
		$59,085.98
Disbursements:		
Manager's Salary		$10,133.22
Purchase, U. S. Liberty Bonds		6,404.82
Transfer to Technical Department		6,000.00
Stenographers' Salaries		5,318.79
Booths		4,522.36
Power		4,366.89
Advertising		3,734.77
Building Rent		2,450.00
Traveling Expenses, Manager and Assistants		2,104.87

Printing and Stationery	1,578.91
Traveling Expenses, Committee	1,561.25
Installation Labor and Material	1,143.95
Installation, Superintendent & Assistants	1,094.00
Bonus, C. E. Hoyt	1,000.00
Registration Expenses	906.00
Office Rent	688.00
Badges	610.50
Donation, Institute of metals, Div. A. I. M. E.	500.00
Telephone and Telegraph	466.41
Office Expense	403.67
Watchman and Doorman	335.00
Postage	326.50
Janitor Service	250.00
Purchase of Furniture	241.00
Insurance	152.80
Cleaning and Repairing	162.00
Personal Property Tax	34.85
Bank Exchange	23.96
Accrued Interest, Bonds	16.88
General Expense	129.89
Refund, Space Rental	230.00
Refund, Permits	150.00
Reserve Fund Interest transferred	45.68
	$57,087.07
Cash Balance as at December 31, 1923—Exhibit A	1,998.91
	$59,085.98

Standard Trust & Savings Bank	$ 1,498.91	
Petty Cash	500.00	
	$ 1,998.91	

Exhibit G.

AMERICAN FOUNDRYMEN'S ASSOCIATION

Department of Exhibits
Statement of Surplus
As at December 31, 1923

Balance, August 31, 1922, per Audit Report			$19,752.55
Adjustments affecting prior years:			
Deduct: Accounts Receivable written off	$	259.76	
Depreciation written off 1920-1922		140.55	
Refund 1922 Permit		25.00	425.31
			$19,327.24
Add: Refund received on advertising	$	6.25	

Refund Insurance Premium	1.26	
Recoveries on accounts written off	1.23	8.74
		$19,335.98
Excess of Income over Expenses for the period ended December 31, 1923—Exhibit E		5,741.03
Deduct: Transfers to Technical Department ...	$ 6,000.00	$25,077.01
Transfer to Reserve Fund	16,078.48	22,078.48
Surplus Balance, December 31, 1923—Exhibit A....		$ 2,998.53

British Foundry Practice—Ferrous and Nonferrous

By Dr. Percy Longmuir, Sheffield, England

Introduction

The following paper written under the stress of high pressure has been prepared with considerable pleasure in that it gives the author a very welcome opportunity of renewing acquaintance with an association whose proceedings contain four of his earliest papers.* These early papers offer a natural starting point for the present one in which it is intended to present a review of metallurgical development in British foundry practice. The sequence of such a review ought to commence in Egypt about 2000 B. C., to follow up to the period which in Britain showed the development of the *Bronze Age* and its passing into the *Iron Age* at least a century before the first Roman invasion. The over running of the North of England by the Scandinavians led to a very material development of the iron industry and within a very short radius from where these notes are being written** are strong evidences of early iron production. These evidences include direct production of wrought iron developing later into after treatment by rolling and the introduction of grooved rolls, the mills being driven by water.

* "Control of the Foundry," June, 1901.
"The Relation of the Laboratory to the Foundry," June, 1901.
"Cast Iron," June, 1902.
"Notes on the Microstructure of Cast Iron, June, 1903.

** Wortley, near Sheffield, England.

This paper is one of a series on foundry problems being exchanged between the Institution of British Foundrymen and the American Foundrymen's association. The first, prepared by George K. Elliott of the American Foundrymen's association, was presented at the 1921 meeting of the Institution of British Foundrymen. The second was presented in person at Rochester, N. Y. by F. J. Cook, past president of the Institution of British Foundrymen. Prof. Enrique Touceda presented the third exchange paper before the British society in 1922. The author of this, the fourth exchange paper, is one of the foremost figures in the British foundry industry. He is a past president of the Institution of British Foundrymen and director of the British Cast Iron Research Association.

Following the revival by Darby of Dudley's coking process the natural development of blast furnace practice had its corresponding effect on gray iron foundry progress and ultimately on the development of steel founding.

British foundry practice today owes a considerable debt to the early effective pioneering work of Professor Turner, and his investigations of the action of silicon upon cast iron* not only gave a definite impetus to foundry development but had the further valuable incentive of turning many other workers towards systematic investigation of cast metals.

The comprehensive work of Hadfield, beginning with alloys of iron and manganese** and continued through many other possible combinations has led to vast extensions in the field of ferrous metallurgy and consequential development of steel foundry practice.

Arnold in his classical research on the "Influence of Carbon on Iron"*** published in 1895, paved the way for definite studies of constitution which have since been developed and advanced by many European workers to the profit of metallurgy in general and foundry science in particular. The reports of the Alloys Research committee of the Institution of Mechanical Engineers, the proceedings of the Iron and Steel Institute, the Institution of British Foundrymen, the Institute of Metals and many other live organizations all contain definite evidence of substantial forward movement. In addition the universities of Britain are doing particularly good work in advancing the outposts of the known into the unknown. In view of the extent of this work it is impossible to refer to it in detail but reference should be made to the valuable work of Desch in Sheffield and Turner in Birmingham universities.

In his 1901 paper before this association, "The Relation of the Laboratory to the Foundry," the author concluded with:

"The future of all foundry work depends upon the development of scientific methods, and from the foothold these methods have already obtained we see the dawn of an era

*Journal of the Chemical Society, 1885.

**Manganese in its application to Metallurgy—The Institution of Civil Engineers, Feb. 28, 1888.

***Institution of Civil Engineers, Vol. CXXIII.

which will be distinguished by a great advance of the whole foundry industry."

The intervening 22 years have shown that the "foothold" then indicated has become firmly established and scientific method has become a factor in all the more important British foundries. Undoubtedly the success of this establishment is due to the fact that it has progressed hand in hand with practice thereby resulting in the development of the latter.

Chemical and metallographical laboratories have proved of high value to practice. Equally on the other hand experienced practice of the foundry floor and the melting platform have proved invaluable to the laboratories.

Whilst this united development has taken place it can but be admitted that each forward step has simply increased the extent of the unknown. After all this is but a natural law and the breasting of one hill just opens vistas of other hills yet to be climbed.

It must be remembered that 22 years ago engineering practice was receiving more attention than foundry practice. Therefore the foundry had a certain leeway to make up. During this period of making up engineering practice has not been stationary. Therefore the foundry has not only had to make up lost time but also to make the further endeavor to overtaking present development in industries whose foundation depends upon a supply of reliable castings. The extent of this achievement has been admirably shown in Mr. Cook's exchange paper of last year.

Gray Cast Iron

The range of iron ores available to the blast furnaces together with the range in practice of the furnaces affords the British iron founder a wide choice of pig iron. This choice can be supplemented by varying additions of mild steel and ferroalloys and therefore a very wide range in product is possible.

The extent of the studies devoted to this product is well shown in the proceedings of the Institution of British Foundrymen. Not only is the range in composition great but equally so is the type of casting. The development of high speed in-

ternal combustion engines has created a series of exceedingly intricate castings and the author has unique opportunities of seeing how admirably the founder is meeting these difficulties. In weight alone the range is equally great; Riddell of Falkirk will successfully reproduce an ordinary tree leaf in cast iron, using the leaf as a pattern. T. Firth of the Brightside Foundry & Engineering Co., Sheffield, produces castings of the type shown in Fig. 1 weighing 106 tons (2240 pounds per ton.)

Advantages and disadvantages of the iron melting cupola were well drawn in Mr. Elliott's exchange paper before the Institution of British Foundrymen in 1921. However, the ruling factor of cost supplemented by the fact of the general efficiency of the cupola melted products will require much con-

FIG. 1—INGOT MOLD WEIGHING 106 TONS

sideration before the adoption of the duplex electric furnace process. As indicated by Desch in discussing this paper the natural economic avenue for the electric furnace is in the direction of steel castings.

In Britain work is being carried out in the direction on the one hand of increasing cupola efficiency and on the other of studies in hearth furnaces including coal, oil and gas firing. It is in one of these directions that future economic develop-

ment of melting for gray iron and alloyed cast irons will take place.

Malleable Cast Iron

In British practice "white heart" predominates over "black heart" so far as quantity is concerned. A good range of white, semi-mottled and mottled pig irons is available. Many of the furnaces also supply "refined" pig irons. When an open-hearth gas fired furnace is the melting medium, "refining" of the bath is permissible. Crucible melting is still largely followed especially in the Midland area but bulk work is generally from cupola melted metal. Coal fired reverberatory or gas fired open-hearth furnaces are utilized and the development of the industry points to the growing use of the latter.

Representative melting practice is shown in the following table:

Method of Melting

	Charge	Crucible	Cupola	Coal-fired Reverbera-tory	Gas-fired Open-hearth
	Per cent	Per cent	Per cent	Per cent	Per cent
Carbon	3.5	3.4	3.4	3.2	3.2
Silicon	0.85	0.82	0.75	0.65	0.70
Manganese	0.20	0.10	0.10	0.10	0.10
Sulphur	0.25	0.30	0.31	0.27	0.26
Phosphorus	0.05	0.05	0.05	0.05	0.05

Average commercial castings give a maximum stress of from 20 to 28 tons per square inch, with elongations of from 2 to 6 per cent on 2 inches and reduction of area of from 2 to 8 per cent. Cold bending tests on one-half inch square bars range from 45 to 90 degrees. A series of commercial castings of Scottish origin tested by the author gave the following results: Analysis, silicon, 0.65; manganese, 0.15; sulphur, 0.30; and phosphorus, 0.04 per cent. The maximum stress in tons per square inch was 27.0, the elongation in two inches was 5.7 per cent and the reduction of area was 10 per cent.

In the field of British malleable cast iron Hadfield has done most valuable pioneering work.* Reference should also be made to some promising work by Royston in 1897**. Roy-

*Iron and Steel Institute Journal 1906 No. 2 and Cast Iron in the light of recent research.

**Journal Iron and Steel Institute 1807 No. 1. In contrast with these results the author cannot help but quote Table I of Professor Touceda's exchange paper to the Institution of British Foundrymen in 1922.

ston's early work apparently lay in the direction of an endeavor to obtain quick if not instantaneous decomposition of the hard carbides and thereby shorten the annealing time. Today this idea is well worth investigation along the lines of determining critical ranges in the near vicinity of the solidification range. A certain amount has been done in the way of laboratory experimental work and in 1904 the author obtained this quick decomposition and resultant precipitation of temper

Table 1

American Methods of Manufacture of Malleable Iron Castings
Analysis of Hard Iron

Mark	Silicon	Phosphorus	Sulphur	Manganese	Combined Carbon
1	0.76	0.193	0.05	0.20	2.13
2	0.88	0.180	0.051	0.23	2.26
3	0.80	0.190	0.049	0.20	2.37

Physical Tests

Mark	Maximum Stress tons per sq. in.	Elongation % on 2 in.	Reduction of area of
1	26.5	36.7	38.0
2	26.1	35.9	33.2
3	25.8	25.7	30.1

carbon by heating to temperatures near the fusion range. However, investigation on practical lines is required in which limiting foundry conditions, influence of mass, change in section and contour of casting and resultant possibilities are included.

In view of the masterly paper of Professor Touceda previously referred to, the present author feels much diffidence in dealing with malleable cast iron. However, it cannot be denied that British malleable iron practice offers a most promising field for research. In this respect the author can only re-echo and appreciate Professor Touceda's sentiments of co-operation between the two countries.

In closing this note on malleable cast iron it is permissible to refer to a casting recently selected at random in a British foundry. Ductility under a striking hammer was so evident that analyses and metallographical examinations were

made. The analysis showed total carbon, 0.03; graphitic carbon, nil; silicon, 0.52; manganese, 0.17; sulphur, 0.292; and phosphorus, 0.049 per cent. Microscopical examination showed structure to be built up mainly of ferrite with involved iron and manganese sulphides. Fig. 2 reproduces a typical field and in the absence of the sulphides this is structurally equal to the purest Swedish wrought iron.

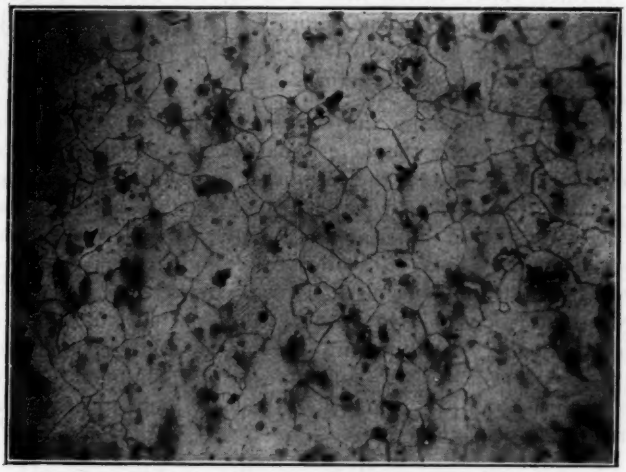

FIG. 2—MALLEABLE CAST IRON. X100

Steel Castings

Systematic steel casting in foundries began in Britain about 1856 and Vickers was one of the first successful workers in this direction. He was followed by many workers among whom may be mentioned Attwood, Rogerson, Spencer and Orborn. The Paris Exhibition of 1878 apparently gave an impetus to steel founding in the exhibit of the Terre Noire Co. Early developments were necessarily of the "trial" order and naturally many errors had to be eliminated. In this patient persistent work lies the foundation of the steel casting industry of today. This early practical work followed by the researches of Hadfield, Stead,

Arnold, McWilliam and many other workers not only opened up scientific possibilities but further led to united practical and scientific attack on the problem of steel casting.

In todays commercial practice crucible melting is followed to a limited extent only. The bulk of the castings are produced from acid and basic open-hearth furnaces, bottom or surface blown convertors. The electric furnace is gaining ground in steel foundry practice and by virtue of its elasticity offeres an excellent medium for the production of special and alloy steel castings.

Generally speaking the metallurgy of steel castings has as its first concern the determination of the most suitable composition to meet the required mechanical properties. Secondly the process whether open hearth, surface blown or electric should finish with a bath of "killed" i.e. dead melted steel. This is achieved by judicious conduct of process and judicious use of deoxidizers. In regard to process it is possible to produce high purity with little or no addition. The following pure iron casting, analyzing carbon .04; silicon .02; manganese .07; sulphur .02; and phosphorus .02 per cent, was crucible melted and killed with a trace of aluminum

	Yield Point Tons	Max Stress Tons	Elongation Per cent 2 inch	Reduction area Per cent
As cast	10.7	19.8	30	39
Annealed	9.1	19.2	46	65

Purity of this type is hardly commercial but at the same time the results give the properties of pure iron in the cast and treated condition.

Additions of carbon to such an iron would progressively stiffen it but experience has shown that carbon alone is not sufficient at any rate so far as castings are concerned. For this reason the two most familiar deoxidizers—silicon and manganese—are either singly or combined added to leave a predetermined excess in the finished steel.

A steel casting containing carbon 0.34; silicon 0.15; manganese 1.58; sulphur 0.06; and phosphorus 0.06 per cent gave the following values:

	Yield Point Tons sq. in.	Maximum Stress Tons per sq. in.	Elongation Per cent on 2 ins.	Reduction of area Per cent	Bending Angle (degrees)
As cast	23.1	35.8	8	9	33
Annealed ..	17.3	32.1	21	28	180

The influence of special elements is naturally a very large field and the following results* are given as representing only a small section of this field.

Nickel steels in the cast condition reheated to and cooled from 800 degrees Cent.

Contents of						
Nickel	Carbon	Manganese	Yield Point tons per sq. in.	Maximum Stress tons per sq. in.	Elongation Per cent on 1.75 ins.	Reduction of area Per cent
Nil	0.47	0.95	19.24	38.49	15.42	16.26
1.20	0.48	0.79	22.07	43.23	14.28	14.88
2.15	0.47	0.86	25.79	42.84	17.70	23.51
4.25	0.40	0.82	28.11	43.49	13.10	17.94
4.95	0.42	1.03	36.00	56.09	14.28	24.43
6.42	0.52	0.92	37.13	57.51	6.20	8.42
7.95	0.43	0.79	41.47	74.03	4.50	5.68
12.22	0.41	0.85	39.85	71.19	6.20	6.88
15.98	0.45	0.83	31.59	76.55	4.00	4.21
19.91	0.41	0.96	17.94	29.69	14.30	19.05

*Seventh Report to the Alloys Research Committee, Iron, Nickel Manganese Carbon, Alloys. Carpenter, Hadfield & Longmuir.

Nonferrous Foundry Practice

Possibly in no branch of foundry practice are accurate analyses so vital as in the case of brass and bronze foundries. The comparatively high intrinsic value of the constituent metals amply justify any cost incurred in checking raw materials.

British melting practice embraces coke fired crucible, coal fired reverberatory furnaces and various types of oil or gas fired furnaces.

The constituent metals vary in physical properties and density and the following table records typical results obtained from commercially pure metals in the sand cast untreated condition.

Properties of Metals as Cast

Metal	Maximum Stress, Tons per sq. in.	Elongation Per cent on 2 ins.	Specific Gravity
Copper	8.1	9.2	8.8
Zinc	1.5	..	7.15
Tin	2.0	30.0	7.29
Lead	1.5	36.0	11.35
Nickel	16.2	4.5	8.84
Aluminum	5.1	5.3	2.65

These results amply illustrate the value of alloying. The range in type of alloys produced is infinite and practice here seems to cover every possible variety of combination.

Two important practical points are worth mentioning:—

(1) From an economic point of view the strict classification of scrap into its respective grades including borings and turnings.

(2) Making good volatilization losses before casting. This is of special importance in the case of high tension brasses, the foundation of which are in the neighborhood of 60 per cent copper and 40 per cent zinc. Irrespective of any third metal present it is imperative that any zinc losses during melting be made good before casting.

Typical physical properties of commercially sand cast alloys are given in the following table:

Alloy	Copper	Zinc	Tin	Maximum Stress Tons per sq. in.	Elongation Per cent on 2 ins.
Red brass	90.0	10.0	...	12.6	26.0
Yellow brass	70.0	30.0	...	13.0	43.0
Muntz metal	60.0	40.0	...	19.0	15.0
Gun metal	88.0	2.0	10.0	18.0	11.0
Gun metal	86.0	4.0	10.0	17.0	10.5
Gun metal	87.0	5.0	8.0	15.0	9.0

A Characteristic Feature Common to all Castings

There are many features common to all grades of castings. Liquid shrinkage, solid contraction and its resultant warping are familiar to all founders varying in intensity according to the type of metal or alloy handled. At the moment it is impossible to touch on these interesting fea-

tures but there is one comon characteristic on which the author would like to dwell for a few moments. This is the influence of varying casting temperature on the physical properties of cast metals and alloys.

Some years ago hard practical experience in the production of high pressure fittings led to the recognition that for a given metal or alloy, one range of pouring temperature would produce a pressure tight casting whilst another pouring temperature from the same ladle would result in a porous casting.

Detailed investigation gave results of the order shown in the following tables:—

Metal	Casting Temperature Degrees Cent.	Maximum Stress Tons per Sq. In.	Elongation Per cent on 2 Ins.
Zinc.....	580	1.30	....
	528	1.81	....
	491	1.37	....
Aluminum.....	725	4.48	2.5
	691	5.62	8.5
	662	5.12	5.0
Copper.....	1500	6.60	8.5
	1446	7.80	11.0
	1141	8.80	8.0
Lead..... ...	580	1.13	18.0
	430	1.43	35.0
	360	1.30	42.0

GRAY CAST IRON

C C	Gr.	Si	Mn	S.	P	Casting temperature Degrees Cent.	Maximum Stress Tons per Sq. In.
0.52	3.4	1.78	0.28	0.04	0.27	1400	9.7
						1350	14.1
						1245	10.6

MALLEABLE CAST IRON

Casting temperature degrees Cent.	As Cast maximum stress tons per sq. in.	Annealed maximum stress tons per sq. in.	Heated to 1000 degrees Cent. slowly cooled
1320	10.7	20.6	18.6
1230	15.9	29.2	24.0
1120	12.1	26.5	21.6

ANNEALED STEEL CASTINGS

C	Si	Mn	S	P	Casting temperature	Maximum stress tons per sq. in.	Elongation per cent on 2 ins.
0.29	0.07	0.16	0.07	0.06	High	24.2	9.5
					Fair	27.2	24.0
					Medium	27.0	12.5
					Low	25.5	8.0

ALLOYS

Alloy	Casting temperature	Maximum stress tons per sq. in.	Elongation per cent on 2 ins.
Gun Metal.....	High	8.38	5.5
	Fair	14.84	14.5
	Low	11.02	5.0
Yellow Brass.....	High	11.48	37.7
	Fair	12.71	43.0
	Low	7.45	15.0
Red Brass.....	High	6.85	13.2
	Fair	12.65	26.0
	Low	5.67	5.5
Muntz Metal.....	High	12.45	6.0
	Fair	18.89	15.0
	Low	16.29	9.5

The foregoing results are selected from a large series and in each instance represent the contents of one crucible or one ladle. The method being to superheat the metal or alloy and pour one set of bars at the "high" heat; the crucible then being allowed to stand until the temperature had fallen to the "fair" heat and then pour the second set. The third set or "low" heat represent the lowest safe pouring temperature. The physical results given show within the contents of one crucible a wide range of properties due to casting temperature alone. An equally wide range is found if a series of valve bodies are cast from one crucible from very hot at intervals down to as low as fluidity is possible. The castings corresponding to the "fair" heat will be tight to internal pressure whilst on either side of the "fair" zone there will be porosity.

Although many actual casting temperatures have been determined only comparatively few have been quoted in terms of degrees Cent. This for the reason that there cannot possibly be a constant "fair" casting temperature for any given alloy to cover every type of casting made in that alloy. Correct casting temperature must necessarily vary with the contour and section of the castings and it is in this direction where trained foundry judgment can exercise its skill to the advantage of the product.

Finally the author expresses his sincere regret that circumstances will not permit him to be present when this paper is read. He can however take comfort by regarding this present absence as a pleasure deferred and hope that on some future occasion that pleasure will be realized.

Graphite in Gray Iron

By J. W. Bolton, Hamilton, Ohio

On reading the foundry papers of today, we note the constant recurrence of such words as scientific, efficient, production, research, metallography and analysis. Some twenty-five years ago these words were little used in foundry circles. Their use today is an indication of new conditions and new factors in the iron industry. Let us consider whether these new conditions, this new era, in the foundry game really stands for better things.

Business men of today understand that ultimate success depends on giving the very best all-round service to the customer. The single price, guaranteed merchandise, and truthful advertising are evidences of this. It's not because it is good morals, but because it is good business that business men look after the customer's interests. The average foundryman realizes this. It used to be, and in many cases still is, that castings were sold on price and weight alone. The cutting prices game proved disasterous to many and it is safe to say that most foundries pay closer attention to their manufacturing costs than they used to. The practice of selling castings on a weight basis alone is wrong for two reasons. First, different classes of castings vary in cost of production. Second, the heavier casting often gives the poorest service. The true basis for selling castings is *service* to the customer. This service may be in the form of better design, of higher quality materials, or of lower cost per year of use. A question of great interest to us today is the production of higher quality materials. The graphite of gray iron is one of the major factors governing quality. Therefore, study of the various phases of graphitization should help us in producing better castings. The foundryman is after practical results. Theory is all right in its place, but theory and research are only means to an end. We must not

let the tail wag the dog. Nothing ever will take the place of good common sense—and true research is a common sense proposition. We say that this new era stands for better things because it means more profits to the progressive foundryman and better service to the customer.

Graphite Influences Quality

The existence of graphite flakes is what makes gray iron a commercial possibility. If it were not for graphitization, it would not be possible to produce a good machinable iron in the cupola. Graphite flakes are what help give gray iron many of its unique engineering properties, such as rigidity and ready machinability. While graphite imparts desirable properties, it also gives some undesirable ones. Among these are little resistance to shock, low strength and open grain. Whether he realizes it or not, the foundryman controls the quality of his castings largely by controlling the formation of graphite.

Since the question of graphitization is such an important one, we need to know enough about it to exercise intelligent control. It is the writer's intention to outline as briefly as possible what we know today about the phenomena of graphite formation.

Graphite is found as weak, pencil-like flakes distributed throughout the metal, as shown in Fig. 1. These flakes are largely graphitic carbon enmeshed in a ferrite (pure iron) network, as illustrated by the microphotograph of Fig. 9. They also contain some sulphides and occluded gases. (See Fig. 12).

Besides graphite flakes, gray iron is made up of varying amounts of pearlite, (Fig. 2) ferrite, (Fig. 3) and steadite (Fig. 4).

The graphite flakes are formed by the breaking down of the combined carbon of the iron during cooling. Some recent work shows that, under certain conditions, the original distribution of combined carbon has an important influence on the formation of graphite. (See Figs. 5, 6, 7, and 9). That is, the first growth and distribution of graphite

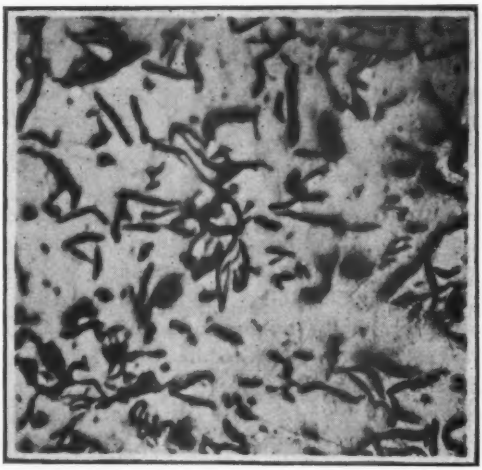

FIG. 1—GRAPHITE FLAKES (BLACK) × 100 DIA., UNETCHED

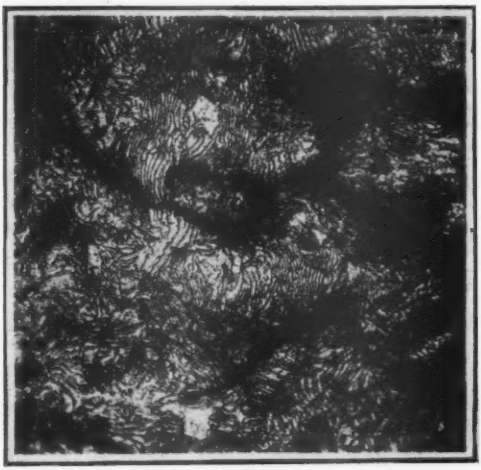

FIG. 2—PEARLITIC MATRIX (THUMB PRINT STRUCTURE) AND GRAPHITE FLAKES (BLACK) × 600 DIA., ETCHED WITH PICRIC ACID

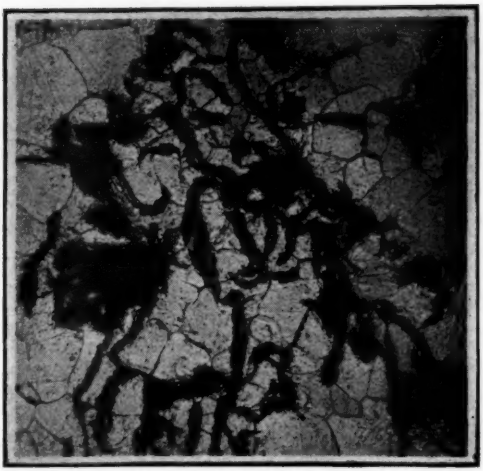

FIG. 3—POLYGONAL GRAINS OF FERRITE SHOWING ALSO GRAPHITE (GRAY WORMLIKE) AND TEMPER CARBON (BLACK) × 100 DIA. ETCHED WITH PICRIC ACID

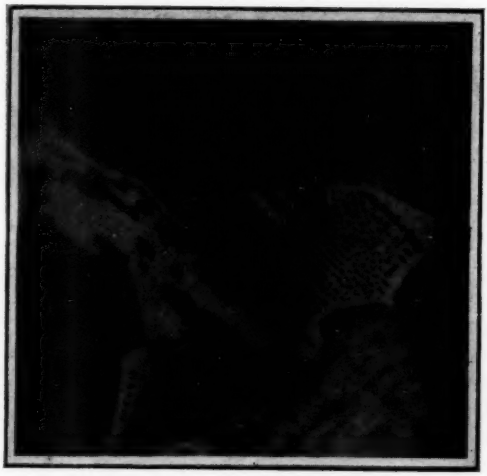

FIG. 4—STEADITE DENDRITE WITH CELLULAR STRUCTURE × 735 DIA., ETCHED WITH BROMINE IN AMYL ALCOHOL

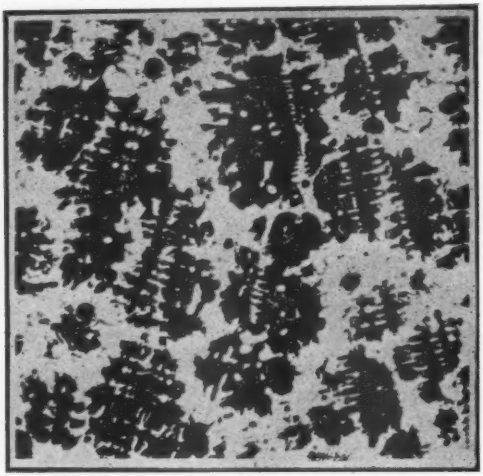

FIG. 5—GRAPHITE FORM RESEMBLING PRIMA AUSTENITE IN OUTLINE × 125 DIA., UNETCHED

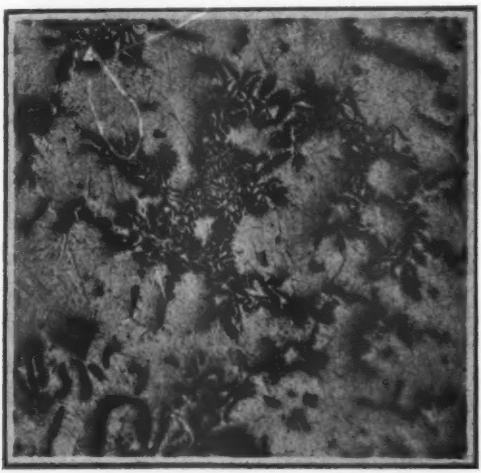

FIG. 6—OUTLINES OF GRAPHITE GROUPS RESEMBLE LEDEBURITE DENDRITES × 100 DIA., UNETCHED

is determined by the form the combined carbon would have taken had the iron been chilled white. This has an important practical bearing on the question of strength, grain, and composition of the iron and will be referred to later.

Graphite influences the physical properties of the metal according to its amount, its size, its distribution, and its shape. The bulk of graphitization takes place between the final solidification (eutectic) and the formation of pearlite (the eutectoid). This graphitization ordinarily affects only the free combined carbon which is called cementite, and is found as such in irons with over 0.90 or 1.00 combined carbon. In this case the resulting metal looks like that shown in Fig. 2. Unfortunately, graphitization does not always cease here but takes up carbon from the pearlite as shown in Fig. 12. This reaction is accompanied by the phenomenon of graphite growth, as distinguished from primary graphitization. The result is large, coarse flakes of graphite surrounded by weak envelopes of ferrite. This condition causes low strength, brittleness, and open grain. As the writer has pointed out in other papers, it is probable that graphitization of commercial irons proceeds below the pearlite transformation range, ceasing only when the rigidity of the metal prevents further migration of carbon.

Controlling Growth of Graphite Flakes

The growth, or size of graphite is influenced by the rate of cooling, the variation in size of the first flakes, and the condition of the metal layers between flakes. Under present conditions, the rate of cooling is governed largely by section size. Where castings are fairly small and have reasonably uniform sections, the effects of cooling can be balanced very nicely by regulating the silicon. However, in the heavy machine tool work, with the general run of castings from 5 to 25,000 pounds, and sections from one-quarter to 8 inches in depth, the very closest supervision is necessary. That we have established an average of 4150 pounds. (A. S. T. M. bar) for one of our mixtures

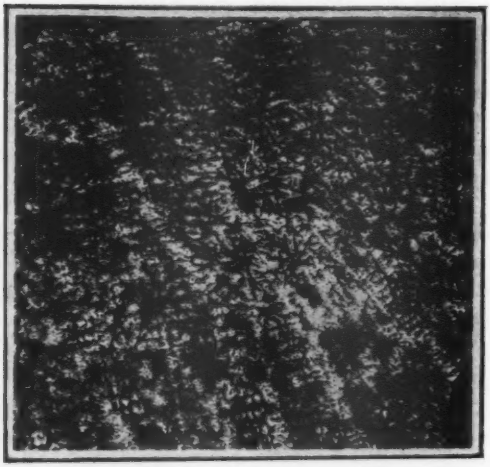

FIG. 7—STRIATED GRAPHITE, RESEMBLING DISTRIBUTION OF CEMENTITE AND AUSTENITE IN HYPOEUTECTIC IRONS. ABOUT 50 DIA. UNETCHED

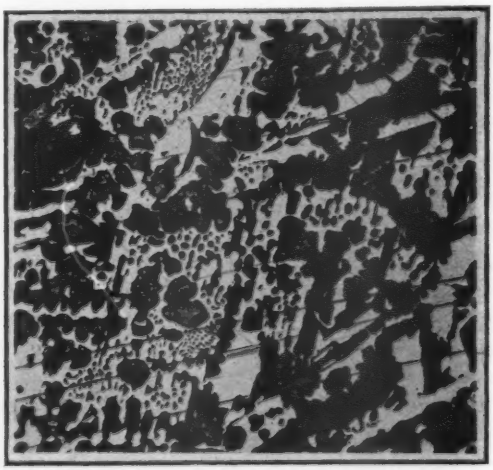

FIG. 8—CHILLED IRON, SHOWING CEMENTITE (WHITE) AND AUSTENITE IN HYPOEUTECTIC STRUCTURE X 75 DIA. ETCHED WITH PICRIC ACID

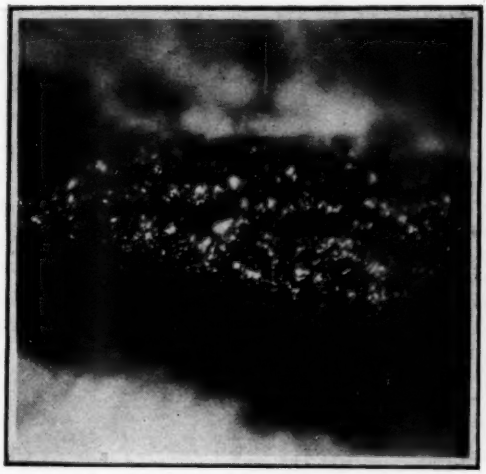

FIG. 9—GRAPHITE FLAKE SHOWING NETWORK STRUCTURE (× 640 DIA.)

FIG. 10—SHOWING BUBBLES OF HYDROGEN SULPHIDE RISING FROM GRAPHITE FLAKES. (× 100 DIA., SHOWING ACTION OF DILUTE PHOSPHORIC ACID)

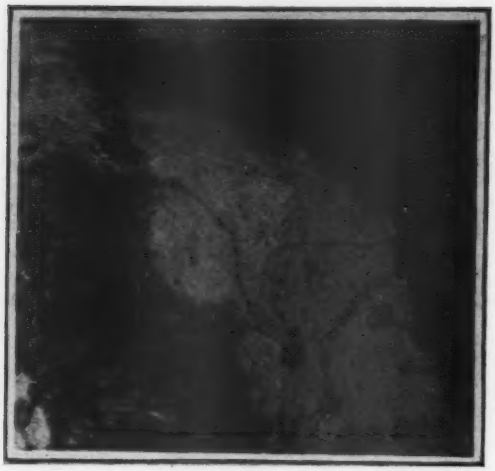

FIG. 11—ETCHING PITS IN FERRITE. × 500 DIA., ETCHED WITH PICRIC ACID

FIG. 12—LARGE GRAPHITE FLAKES SURROUNDED BY BROAD BANDS OF FERRITE. A LOW STRENGTH OPEN GRAIN IRON

(over a long period, not for a day or so) and can produce a reasonably close grain iron in heavy sections is evidence of practical accomplishment.

General laws of crystal growth show that growth is accelerated by having crystals of varying size, so that the large grow at the expense of the small. The practical significance of this is that if we have coarse flakes arising from some pre-existing component, say prima austenite, and small flakes from another say ledeburite, we are more likely to have growth than if the whole structure is fine, say of eutectic composition. This explains why, under certain conditions a higher total carbon may produce a stronger iron. If the iron is of eutectic composition, for example with 3.75 carbon, the initial graphite will be in small flakes and growth may be hindered at first. On the other hand, the presence of more graphite (its mass acting as an accelerator for growth) and the effect of a greater volume of graphite (if growth is at all complete) may have the opposite effect. The fact is that today we cannot specify a single optimum carbon for all grades of castings. All the factors must be carefully weighed. In some places, in very heavy sections low carbon may be best. In small sections it is likely that rather high carbon will give the desired results. If, beside the actual flake structure of the graphite, we consider the variations in melting practice necessary to produce different carbons, and the possible effects of these changes, we see that the carbon question is indeed a complex one.

Effect of Silicon

Silicon is the element by which the foundryman manipulates his carbons, controlling the ratio of combined to graphitic. The exact mechanism of silicon action is not completely worked out. It behaves much like carbon in the iron crystal, suggesting possible interchangeability. It lowers the amount of carbon required for the eutectic so

that for small castings higher silicon and lower carbon should give better results than higher carbon and lower silicon.

Foundrymen Favor Low Carbon for Strong Irons

In order to make this paper more interesting to the practical foundryman, questionnaires were sent to a number of leading foundrymen and metallurgists. The questions were designed primarily to find out just how the industry thinks about the carbon-graphite question. The answers show that ninety-five per cent of the men questioned favor low total carbon for high strength—high deflection irons. To get an iron 4000 pounds transverse test on the A. S. T. M. bar, silicons ranging from 1.10 to 2.35 per cent were advocated. This is quite a range, especially when the majority recommended 3.00 to 3.25 per cent carbon to accompany the same. The majority advocatd phosphorus about 40 per cent, ranging from 0.30 to 0.60 per cent. Sulphur up to 0.10 was specified. The general opinion was that the manganese should be 0.50 to 0.80 per cent.

The fourth question asked what should be the proper factor for converting transverse to tensile strength. Answers varied from 6.70 to 9.30, a difference of over 25 per cent. It was brought out that quite a number of foundries do not use the A. S. T. M. bar. The writer thinks, as a result of conducting a number of tests on various size and shape bars that it is not accurate to convert tests using the section moduli. We have to use the same bar to get comparison, and the bar must be 1.25 inch, not 1.40 or 1.10 inch. (i. e. caliper the bars). We could take a square bar, get a high deflection and strength, then figure it to a round, with considerable advantage to the results. But no one would be fooled except ourselves. Also, the apparatus for measuring deflection should be specified. We want the bend of the bar itself, not the relative movement between the center knife edge and the table. The testing societies should specify how this test should be made.

The majority of those who answered felt that 15 per cent to 20 per cent steel gives the best results. None ex-

pressed any decided preference for machine or sand cast pig. A number recognized causes of open grain other than high graphite. In this connection it should be mentioned that an open grain iron with a ground finish will present a better appearance than a close grain iron finished on a lathe or planer. The microscope furnishes the only means (beside fracture) of distinguishing the real grain structure in all cases.

All the above data shows one thing. There is no short, easy road to success. There is more than one road to Rome—and there are a lot more which lead in other directions. Foundry metallurgy needs more fundamental research before the roads to Rome can be pointed to with certainty.

One part of this needed research is the study of the influences of graphite. We know enough about graphitization to improve a number of types of castings. Much more work is needed before we will know what to do for each particular job.

Discussion—Graphite in Gray Iron

C. E. Sims.—I was interested in the discussion of sulphur in the cylinder blocks. Sulphur is the question that keeps recurring constantly. It refers back to this carbon in the iron. Certain foundrymen have high running silicon and soft looking iron. We couldn't get the silicon down so we raised the sulphur and the silicon has disappeared. Sulphur seems to hold the grain size down. Actual sulphides occur right in the graphite plates. We are not particularly afraid of high sulphur. I know that a lot of people think that when sulphur gets around 0.10 it is terrible but we are reasonably successful when our sulphur is around 0.10 and 0.12. By running too much air in the sulphur and the oxygen seem to unite, and you have a lot of spot holes.

Dr. R. Moldenke.—Dr. Porter had that same theory. He said sulphur was all right as it is, but he put oxygen in and he couldn't do anything with it. It caused sulphur blowholes. The air striking on the iron forms SO_2. The oxidation of sulphur is as important as the oxidation of iron. Nine-tenths of the blame on sulphur belongs to the oxygen.

J. D. Stoddard.—I am very glad to hear Mr. Bolton say they are not afraid of sulphur. I believe that sulphur is the "goat." I believe with the average foundryman, that high sulphur is bad for ordinary practice. It is a fact that you can make good castings with exceedingly high sulphur.

H. Traphagen.—I had the pleasure of being associated with J. E. Johnson for a number of years, and we found a peculiar relation between the oxidized condition of the pig iron and the sulphur content, and that condition relates back and depends upon blast-furnace practice more than anything else. It seems that that peculiar condition in this form of pig iron is due to the fact that the pig iron is literally half-cooked. The fine ore gets down into the molten metal and dissolves, then you get an extremely strong pig iron. My experience has been that in every instance the sulphur is remarkably low unless you know the method of getting at it. The only way that you can get the sulphur out of that peculiar form of pig iron is with the extended fusion process. Sulphur is a bug-bear, as Mr. Stoddard has said. We look upon the sulphur content as an index quality, which is an easy thing to determine, but I think that the more the question is delved into the more we will all be convinced that sulphur in itself does not mean anything except as an index to melting conditions.

Dr. R. Moldenke.—That is very interesting and in the main correct, but we are getting to the point where we are making sulphur too good. What you mention there is oxidation. I myself, feel, too, that it doesn't matter very much in ordinary castings, but when you come to the question of shock then the sulphur does make a terrific difference, for

instance, in a water pipe that the plumber comes along and hits. Where shocks are involved it is very dangerous.

J. W. Bolton.—Isn't it true in the case of sulphur the same as in the other elements in iron—we might say silicon is a good thing in its place, and so with sulphur. We can make it serve its purpose in its place if we use discretion with it, isn't that the point of the whole argument?

Notes on Gray Iron for Automotive Castings

By H. B. SWAN, Detroit, Mich.

Some time ago the writer was requested to prepare something on gray iron mixtures for automotive castings. It hardly seemed as though a sufficient amount of new data had developed since the writer had previously presented a paper before the 1913 meeting of this association on this same subject to warrant such a paper. However, it appeared that some discussion of the general practice in this country on that subject might be of some interest. With this in view, it was suggested that a questionnaire covering the data required be prepared and sent to a representative list of the foundries supplying the automotive industry. About twenty-five foundries comprised the list prepared and replies were received from sixteen. Many of the latter were incomplete in the answers to questions asked. In regard to the cupola data asked for, it was thought interesting to find out whether the present day practice approached anything which might be called standard. Furthermore, the writer desired to check up some personal observations regarding the total carbon content. The amount and condition of the total carbon is to the writer a point of prime importance for such work as cylinders. Fuel ratio, the percentage of pig iron, remelt and steel are important both technically and economically. The amount of remelt which can be used without detriment to the casting is a point often discussed. The question of what mixture the foundryman shall use depends on several factors. It may happen that the buyer furnishes certain specifications by which the foundryman must be guided to some extent in compiling his mixture. Special physical tests are not uncommon. In other instances the composition is left entirely to the judgment of the foundryman. Of course,

good machining qualities and freedom from the usual foundry defects are understood. As an instance of special requirements, the writer recalls a rather difficult exhaust manifold which the foundry was called upon to make. This casting was polished all over the outside surface previous to a bake enamel. Being a thin walled casting with some comparatively heavy bosses and flanges, it required considerable experimenting to get the iron which filled all requirements satisfactorily. Another instance, is a company which requires that the barrels of the cylinder block shall conform to a Brinell test within certain limits. It often requires the best judgment of several years' experience and some experimental work to meet special specifications for a peculiar casting.

Classes of Automotive Castings

Automotive castings may be conveniently divided into the following classes:

1.—Cylinders, cylinder heads.
2.—Pistons.
3.—Crank cases and transmission cases.
4.—Flywheels and gear blanks.
5.—Miscellaneous small castings, such as manifolds, pumps, covers, etc.
6.—Piston rings.

In making the above divisions, due consideration is made for the shop wherein questions of tonnage, melting capacity, ability to take care of special mixtures from the same cupola, price, etc., are questions of vital importance. On the other hand, a special iron will oftentimes cut down losses and be an economy in the end, in addition perhaps, to meeting the service requirements of the casting most suitably. For instance, for cylinder blocs, which are not cast integral with the upper crank case—it is desirable to have them as hard as the machining will stand. The writer's observation extending over a period of years, is that hard barreled cylinder blocs wear best in service. This statement is made on the basis of the number of cylinders returned from service for regrinding, from each year's model.

In the writer's experience, cylinders of a proper hardness and composition will run from 30,000 miles to better than

50,000 miles in some cases before needing to be reground. Of course, there are several factors in motor operation which govern the wearing qualities of the barrels, notably, lubrication and the richness of the explosive mixture. Cylinders cast integral with the crank case and crank cases themselves usually require a softer and tougher iron, due to the thin walls and large area to be covered and liability to cracks.

Piston rings are a specialty in themselves, and pistons are better made from special mixtures. Fly wheels and gear blanks could well be made in the miscellaneous class, but for the fact that where teeth are cut in them a harder iron wears better. Cylinder iron is usually satisfactory for these castings.

For a detailed method for computing mixtures allowing for losses, the effect of varying the element constituents in gray iron, etc., those unfamiliar with the practice are referred to Dr. Moldenke's "Foundry Practice" and to such articles as Dr. John J. Porter's "Constitution of Cast Iron," Vol. XIX, *A. F. A. Transaction*. A few words along this line, however, may not be amiss. For the foundry making the aforementioned classes of castings, a fair assortment of pig iron in the yard is quite desirable, if not necessary. This stock may preferably include, first a grade of foundry iron best adapted to the general run of work in the shop; secondly a silvery iron (7 to 10 per cent silicon); malleable bessemer; perhaps charcoal iron for special purposes, and selected scrap and scrap steel.

For such work as cylinders, the writer has found that in using scrap steel better results are obtained in the use of steel of fairly good section, such as rails, medium forgings or heavy boiler plate clippings. Drop forge flashings are cheaper but light and oxidize more readily. Where more than one mixture is used in a shop it is necessary to use care in keeping the remelt separated, if castings of uniform analysis are to be obtained. Under these conditions it is possible to easily vary and control the silicon, manganese, phosphorous and sulphur contents. Silicon is controlled by

varying the amount of silvery iron and scrap steel used, manganese by the use of the ferroalloy or spiegel; phosphorus, in amount of steel used and perhaps by using some high phosphorus pig if it be necessary to raise its percentage; sulphur can to a lesser extent be controlled through the manganese content and by the temperature of melting and slag proportionment. (See J. Bolton, *Foundry*, Sept., 1921).

The carbon content is much more difficult to control, for the iron will take up carbon to the saturation point, depending on the temperature and silicon content, a mixture with a high silicon content, that is 2.75 to 3.00 per cent and fairly high sulphur tends to reduce the total carbon. Moreover, melting lower than the correct level above the tuyeres in the cupola has the same tendency. Higher melting has the opposite effect. Then with a full understanding of the relations of each element and their functions, together with close melting control, it is not difficult to run an iron mixture from day to day with a small variation in composition. Of course, it is understood accurate information is at hand concerning composition of all the raw materials affecting the final product and frequent analyses, hardness tests, fracture examinations, pouring temperature observations, and sometimes physical tests are necessary adjuncts to close control and getting the most desirable results.

Referring to the tabulated data shown in Table I, it is to be noted that the information shown is representative of the practice of the largest corporation foundries in this country, making castings for cars from among the cheapest makes to the most expensive. Where a range of figures was submitted, the writer has averaged them and used the average figure in the table. For instance, where a silicon content is reported as from 2.05 to 2.15 per cent the value used is 2.10 per cent. Similarly in the columns under tensile strength, hardness, etc.

An analysis of the column showing the percentage of pig iron used in the mixture, a range from 34.3 to 56 per cent is found, with an average of 44.1 per cent. The experience of the writer has been that it is not advisable to run

TABLE 1—CYLINDERS

Number	Silicon	Manganese	Phosphorous	Sulphur	C. Carbon	G. Carbon	Total Carbon	Percent Pig Iron	Percent Remelt	Percent Steel	Fuel Ratio	Tuyere Ratio	Blast Pressure	Diam. of Cupola Inside Inches	Tensile Strength Pounds per Sq. In.	Trans. Break ¼ inch dia. Ar. Bar 12 Inch Centers	Deflection in Inches	Brinell Hardness
1.....	2.10	.80	.20	.08	.50	2.70	3.20	40	45	15	1:7.27	1:5.9	12	54	.....	....	....	185
2.....	2.50	.60	.55	.15	.45	3.10	3.55	35	40	25	1:5	1:5	15	72	40000	3100	.18	185
3.....	2.25	.65	.20	.10	.40	3.00	3.40	34.3	45.7	20	1:7	1:5	18	78	30000	3000	.15	201
4.....	2.20	.65	.30	.09	.20	3.30	3.50	45	45	10	1:8.3	.....	11	60	34000	3800	.17	...
5.....	2.40	.60	.22	.10	.35	3.00	3.35	43.4	40.6	16	1:6.6	1:10.9	13	66	.....	3000	.14	181
6.....	2.20	.65	.45	.09	.50	2.90	3.40	50	37.5	12.5	1:6.8	1: 4.7	16	60	33000	3300	.12	217
7.....	1.75	.55	.25	.08	....	....	.....	50	30	20	1:8.3	1: 5.5	13	54	33500	3350	.16	207
8.....	2.10	.60	.22	.095	.60	2.80	3.40	55	25	20	1:7.7	1: 2.25	14	60	27400	3800	.135	197
9.....	2.25	.60	.25	.10	.45	2.80	3.25	48.9	39.1	12	1:8.5	1: 8.0	14	54	37500	3100	.14	192
10.....	2.10	.60	.20	.095	.60	....	.....	56.0	32	12	1:9.2	.....	16	64	.....	....	....	190
11.....	2.85	.50	.18	.15	.50	2.40	2.90	42	40	18	1:7.4	1: 3.75	11	48	37500	3750	.16	175
12.....	1.90	.70	.18	.08	.50	2.90	3.40	38	44	18	1:6.66	1: 5.4	14	54	30400	4300	.13	170
13.....	2.00	.65	.20	.095	.50	3.20	3.70	40	44	16	1:8.5	1: 6.1	16	70	.....	....	....	175
14.....	2.50	.70	.25	.09	.40	....	.....	53.5	34	12.5	1:7.5	1: 4.1	....	52	.....	....	....	...
15.....	2.70	.55	.20	.10	.50	2.70	3.20	40	37.5	22.5	1:5.9	1: 4.25	11	54	32500	3300	.125	200
16.....	2.05	.60	.15	.09	.60	2.80	3.40	43.3	36.6	20	1:6.66	1: 4.8	....	72	36000	4400	.25	212
*.....	1.20	.80	.35–	.12	.50–	....	2.70–	....	....	....	.....	.....	....	....	.....	....	....	...
A.....	1.80	Max.	.80	Max.	.80	....	3.50	....	....	....	.....	.....	....	....	.....	....	....	...
*.....	1.20	1.10	.60–	.12	.50–	....	2.70–	....	....	....	.....	.....	....	....	.....	....	....	...
B.....	1.80	Max.	1.20	Max.	.80	....	3.30	....	....	....	.....	.....	....	....	.....	....	....	..

* The British Engineering Standards Association Specifications for water cooled air craft cylinders. Foundry Vol. L-3, Feb. 1, 22.

a mixture with less than 40 per cent pig iron for cylinder work. The proportion of steel scrap and remelt to be used depends upon conditions, such as the amount of remelt available in your own shop and from the rejections from your buyers, also on market conditions. It is easier to buy uniform steel scrap than uniform gray iron scrap.

Carbon

Again referring to the tabulated data it is found that the percentage of remelt, scrap, sprues, gates, etc., varies from 25 to 45.7 per cent with an average of 38.5 per cent, and the scrap steel content from 10 to 25 per cent, averaging 16.8 per cent. The advantages and disadvantages, if any, in the addition of scrap steel to a mixture have been so widely talked of that it is unnecessary to discuss them here. Steel is a very handy tool for the formulator of the mixtures, as previously pointed out, and in the writer's experience, under proper melting conditions there is little to be said against its use. For this class of work, however, most of the desired results can be obtained with the use of from 15 to 20 per cent.

Considering the use of steel scrap in the cupola from the purely physical benefits to be derived, the prime object in its use is the closing up of the grain of the iron. In so far that higher percentages reduce the total carbon content of the spout metal, in the opinion of the writer, this is extremely doubtful. Much more control of the total carbon is to be found in varying the silicon content and in the height of the melting zone in the cupola. That height of melting zone in the cupola which gives the hottest iron will also give the highest total carbon for a given mixture and raising the percentage of steel will reduce the carbon but slightly. Lowering the melting zone will both lower the temperature of the metal and reduce the carbon.

A glance at the columns under total carbon, and under per cent of steel, shows us that the steel has little influence on the carbon. In No. 1 with 15 per cent steel a total carbon content of 3.20 per cent is found, whereas in No. 2

with 25 per cent steel the total carbon content is 0.35 per cent higher or 3.55 per cent. No. 11 shows the lowest total carbon, coincident with the highest silicon and sulphur contents, and its steel ratio is lower than No. 2. The following equation taken from the "Constitution of Gray Iron," by J. J. Porter, A. F. A. *Transaction,* Vol. XIX, gives a fair idea of the effect of the other elements on the total carbon. Per cent T. C. equals 4.23—.27 x per cent Si—.32 x per cent P—.3 x per cent S plus .03 x per cent Mn.

He further adds that:

"The sum of the graphite and combined carbon is dependent upon the conditions of melting in the blast furnace and in the cupola; and upon the percentage of silicon, sulphur and manganese . . . . . ."

As a matter of comparison, the writer has put in table No. 1 the specifications of the British Engineering Standards association for water-cooled air craft engine cylinders. To the writer's knowledge, neither the S. A. E. nor the American Society for Testing Materials have any specifications for automotive castings which could be used for comparison. It is to be noted that the graphite is held fairly low in both sets of figures, the silicon is lower, the manganese higher, and the phosphorus much higher than the average American practice.

Hardness Essential in Bore of Cylinder

As previously stated, the writer's experience shows that cylinders with hard bores give better wearing service. Hardness is a function of grain size as well as composition, and the grain size is a variable with the rate of cooling. That part of the bore of a cylinder which is surrounded by the water jacket is usually the softest part of the casting, and is softer than a test bar, up to 1-inch section, which is poured from the same ladle, due to the different cooling effects. The barrel of the average automotive cylinder is seldom over one-half inch in thickness as cast. The sand of the water jacket core and of the heavy barrel core hold the heat so long that an annealing action is obtained in this

portion of the barrel. This can be prevented to some degree, by the use of hollow steel or iron arbors for the barrel cores covered with only a thin layer, from 3/16 to 5/16 inch of sand, and allowing a free circulation of air beneath the bottom board through the arbors and through the cope if the cylinder is molded on end. This procedure will raise the hardness of the barrels about 30 to 40 points on the Brinell scale. Furthermore, low total carbon is desirable. That is a cylinder from an iron containing 0.50 to 0.60 per cent combined carbon and about 2.50 to 2.75 per cent graphitic is preferable to one with the same percentage of combined carbon and 3.00 per cent or over graphitic.

Silicon

A further study of the questionnaire shows a silicon range from 1.75 to 2.85 per cent with the greater number using 2.10 per cent. All points considered, for the average run of cylinder work this is a very satisfactory content to use. Used in conjunction with low phosphorus, it has one disadvantage in that it is provocative of more shrinkage cavities than such a mixture as No. 11. However, if the total carbon is on the low side, the iron sets quickly enough in all sections to overcome this to some extent.

Manganese

The manganese content, as shown in the table, is remarkably uniform, ranging from 0.50 per cent to 0.80 per cent. Generally speaking, it would seem a slight excess of manganese over the theoretical amount necessary to take care of any ill effects from the sulphur is all that is necessary, although it, perhaps, has some benefits as a deoxidizer.

Phosphorus

The phosphorus ranges from 0.15 to 0.55 per cent with the predominating tendency toward the lower end of the range. This practice of using low phosphorus has increased extensively in the last few years, and is due to the fact that the cylinder manufacturer seeks to eliminate the segregation of the fluid phospho-carbides. In doing this, with a low silicon mixture, much of the fluidity of the iron

is sacrificed, thereby necessitating hotter melting, which means higher total carbon. The factor of strength does not enter into consideration in this class of work, and the irons with higher phosphorous contents are plenty strong, indeed, they will average up well with the lower phosphorous irons.

For obtaining cylinder bores with a high degree of hardness, there is much to be said in favor of the high phosphorous mixtures such as are typified by the examples shown above of the British Engineeriing Standards association, and discussed by Mr. Cook in his paper at the last convention of the American Foundrymen's association. These irons hold their hardness through the cooling range, due probably to the predominating phosphide constituent; and the total carbon content is usually considerably lower than low phosphorous irons of the same silicon content. Unfortunately, in the experience of the writer, with the pig irons obtainable in this country, segregation is a frequent and difficult problem to control when such mixtures are used on complicated castings. With castings of simple design and uniform section very good results can be had. But with low phosphorous irons, the writer's experience has been that the defects due to leaky walls is much reduced.

Sulphur

The column under sulphur in the data sheet shows a range from 0.08 to 0.15 per cent with the average about 0.095 per cent. Present day practice shows an increase in the sulphur content of most grades of castings in this class of work. There are some arguments which can be set forth favorable to a higher allowable sulphur content than was formerly thought possible to use without serious detriment to the casting. Now for this class of gray iron, a predominating pearlite structure is highly desirable. This is entirely in accord with the statement of the writer, made in 1913 (*Trans.* A. F. A. Vol. XXII), and also with the results stated by Zimmerschied (*Trans.* A. F. A. Vol. XXIII) in his paper on "Cast Iron with Unusual Structure." A reference to the *Iron Age* issue of Dec. 30, 1915, shows some of the high strength results obtained in Europe in

experiments with sulphur in high limits in gray iron. Evidently a sulphur content of 0.15 per cent is not too high to be detrimental. The writer believes, however, that with the sulphur at such percentage the silicon should be increased somewhat. The writer knows of one cylinder foundry which has been using a mixture wherein the silicon averages about three per cent, the sulphur 0.15 per cent and the phosphorus under 0.20 per cent, for several years with very good results.

Serviceable Mixture

For a serviceable mixture, all points considered, the writer believes the following mixture very satisfactory to aim at: Silicon 1.80 to 2.10 per cent; manganese 0.50 to 0.80 per cent; phosphorus 0.15 to 0.20 per cent; sulphur 0.08 to 0.12 per cent; combined carbon 0.50 to 0.60 per cent and graphitic carbon 2.50 to 2.75 per cent. Such a casting should machine satisfactorily, give a good close grain, and wear well in service.

By machining satisfactorily is meant that a cylinder bloc cast from this mixture can be milled with a cutter speed of from 60 feet to 80 feet per minute, with a cutting depth of 1/8 of an inch; and bored with a cutting speed of 45 feet to 50 feet per minute with 1/8-inch cut.

Furthermore, such an iron will have a transverse breaking strength above 3500 pounds on the arbitration bar and a tensile strength of over 30,000 pounds. These figures are conservative and taken from actual results in the practice of the writer with iron of the above analysis, save that the total carbons were higher, (about 3.50 per cent). The difficulty in obtaining such iron is in getting the total carbon down to the figures indicated.

Fuel Ratio

Regarding fuel ratio, a variation is found from 1:5 to 1:9.2 with an average of 1:7.33 which is a very good ratio considering the steel ratios, and that this class of work is fairly light, and needs to be melted fairly hot. Coke used on bed is not included in the figures given for ratios.

TABLE 2—PISTONS

Number	Silicon	Manganese	Phosphorous	Sulphur	C. Carbon	G. Carbon	Total Carbon	Percent Pig Iron	Percent Remelt	Percent Steel	Tensile Strength Pounds per Sq. In.	Trans. Break 1¼ inch dia. Ar. Bar 12 Inch Centers	Deflection in Inches	Brinell Hardness	REMARKS
1...	*2.10	.80	.20	.08	.50	2.70	3.20	40	45	15	.....	....	....	...	Same mixture as used for cylinders.
2...	*2.50	.60	.55	.15	.45	3.10	3.55	35	40	25	.....	....	....	...	Same mixture as used for cylinders.
3...	2.40	.55	.18	.10	.30	3.10	3.40	40	44	16	27000	2700	.16	192	Special mixture for pistons.
4...	*2.20	.65	.30	.09	.20	3.30	3.50	45	45	10	.....	....	....	...	Same mixture for all classes.
5...	2.50	.60	.22	.10	.35	3.10	3.45	46.7	41.3	12	.....	2800	.14	174	Special mixture for pistons.
6...	2.60	.65	.50	.06	.25	3.25	3.50	50	45	5	30000	3000	.12	192	Mixture used for all small work.
7...	*1.75	.55	.25	.08	...	....	...	50	30	20	33500	3350	.16	207	Same mixture as used for cylinders and crankcases
8...	*2.10	.60	.22	.095	.60	2.80	3.40	55	25	20	27400	3800	.135	197	Same mixture as used for cylinders.
9...	2.50	.60	.30	.09	.29	3.15	3.40	56.5	41.3	2.2	24000	2450	.16	...	Miscellaneous small castings.
10...	*2.10	.60	.20	.095	.60	....	....	56	32	12	.....	....	....	190	Same mixture used for all classes of work.
11...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	No data given.
12...	2.50	.70	.15	.07	.45	3.00	3.45	45	40	15	24200	3400	.12	160	Special mixture for pistons.
13...	2.40	.65	.30	.095	.35	2.95	3.30	40	44	16	.....	....	....	165	This mixture used on all classes except cylinders.
14...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	No data given.
15...	2.75	.55	.20	.10	.40	2.95	3.35	40	50	10	31000	3100	.125	180	This mixture also used for flywheels.
16...	2.35	.60	.18	.09	.55	2.95	3.50	43.3	46.7	10	28000	3400	.187	196	This mixture also used for crankcases.

* Same iron as used for cylinders.

Under the column on tuyere ratios is found a great divergence in practice with ratios varying from 1:2.25 to 1:10.9. With the exception of Nos. 5 and 10, they are all lower, under 1:6 averaging 1:4.73. Some authorities give 1:7 as the proper proportion, whereas others say about 1:4. Judging from data submitted, there is nothing to be taken as a standard. A comparison of the tuyere ratios to the fuel ratios does not add any light on the subject for No. 8, with a tuyere ratio of 1:2.25 and a fuel ratio of 1:7.7 is little different in fuel consumption than No. 9 with a tuyere ratio of 1:8. It hardly seems possible that there should not be a ratio between the area of the tuyeres and the area of the cupola which gives the best melting conditions. There is a need still for data on cupola design.

Pistons

Table No. 2 on pistons shows the data arranged under the same numbers as in Table No. 1. Some replies gave no data on pistons so that there the spaces opposite those numbers are vacant. Those showing asterisks indicate the same iron used as for cylinders. It is to be noted here that *among those using a special iron* for pistons that the silicon content is higher, running from 2.35 per cent to 2.75 per cent, the manganese content about the same as for cylinders, likewise the phosphorus and sulphur; the combined carbon lower, averaging about 0.35 per cent as against 0.47 per cent for cylinders. The total carbons are about the same as for cylinders. The per cent of pig iron used is a little higher, averaging a little better than 45 per cent, but the percentage of steel is lower, averaging about 11 per cent only. The average precentage of remelt is thereby raised a little, averaging about 44 per cent. These figures would be changed but little even if the mixtures as indicated for cylinders were included. The drop in strength is quite noticeable which is to be expected from the difference in analysis.

Present day practice is to make pistons as light as possible, and extensively with green sand cores. They can be cast with wall thickness as low as 3/32 inch. With such

light sections, however, there is a severe tendency to get chilled spots when using mixtures with low phosphorus. The wrist pin bosses are heavy and there is usually trouble in preventing shrinkage cavities between these bosses and the wall of the piston. A higher silicon content, say from 2.50 to 2.75 per cent, is desirable, for it serves several purposes, counteracting the shrinkage above mentioned, minimizes the blows, and counteracts the chilliing tendency of the quick setting iron. Hot melting is essential for the metal should come from the spout better than 2600 degrees. Another trouble of considerable importance with such light castings is the loss due to cracks. Many machine shops use air expanding chucks holding the piston from the inside and causing considerable strain on the casting. It is well to toughen the iron by the use of a fair percentage of charcoal iron in the mixture, say about 20 per cent. For this purpose the writer has used the Lake Superior charcoal brands to good advantage. For especially high grade pistons, where expense is not of prime importance, from 4 to 5 per cent nickel may be used to advantage, giving a product when machined of beautiful finish, extremely fine grain, and high strength, about 37,000 to 38,000 pounds tensile strength, and uniform hardness.

On pistons, it is good practice after the rough cut in the machine shop to anneal sufficiently to remove casting strains. This to a large extent, prevents the casting from going out of round on the final operations.

Miscellaneous Small Castings

An analysis of the data on small castings given in Table 3 reveals a range from a low silicon, hard iron in No. 3 to soft, rather high silicon irons such as Nos. 12 or 15, with the latter in a predominating majority. No. 3 stands out really as an exception to the usual run of irons for this class of work. It is interesting to note here, as a further instance of the effect of steel on the total carbon, a comparison with No. 8. Both contain approximately the same amount of steel in the formula, but a noticeable difference in the carbon percentages. No. 3 is melted in

TABLE 3—MISCELLANEOUS SMALL CASTINGS

Number	Silicon	Manganese	Phosphorous	Sulphur	C. Carbon	G. Carbon	Total Carbon	Percent Pig Iron	Percent Remelt	Percent Steel	Tensile Strength Pounds per Sq. In.	Trans. Break 1¼ inch dia. Ax. Bar 12 Inch Centers	Deflection in Inches	Brinell Hardness	REMARKS
1...	2.30	.60	.40	.08	.40	2.80	3.20	40	60	....	.....	....	....	...	Same mixture as used for crankcases.
2...	2.50	.60	.55	.15	.45	3.10	3.55	35	40	25	40000	3100	.18	185	Same mixture used for all classes of castings.
3...	1.60	.50	.25	.11	.70	2.45	3.15	25	40	35	*32000	*3200	.14	229	*1 inch x 1 inch x 15 inch used. This mixture used only for small castings.
4...	2.20	.65	.30	.09	.20	3.30	3.50	45	45	10	34000	3800	.17	...	Same mixture used for all classes of castings.
5...	2.65	.60	.22	.075	.25	3.30	3.55	61.6	33.4	5	.....	2200	.16	153	Same mixture as used for crankcases.
6...	2.60	.65	.50	.09	.25	3.25	3.50	50	45	5	30000	3000	.12	192	
7...	2.10	.60	.34	.08	....	....	....	50	30	20	26000	2800	....	170	
8...	2.40	.60	.50	.09	.35	3.10	3.45	56.25	6.25	37.50	21700	2800	.12	170	Same mixture as used for crankcases and flywheels.
9...	2.50	.60	.30	.09	.25	3.15	3.40	56.5	41.3	2.2	24000	2450	.16	...	
10...	2.10	.60	.20	.095	.60	....	....	56	32	12	.....	....	....	190	Same mixture used for all classes of castings.
11...	....	....	....	....	....	....	....	....	....	....	.....	....	....	....	No data given on any class except cylinders.
12...	2.50	.60	.25	.065	.40	3.20	3.60	38	53	8	.....	....	....	145	
13...	2.40	.65	.30	.095	.35	2.95	3.30	40	44	16	.....	....	....	165	Same mixture used for all classes of work except cylinders.
14...	....	....	....	....	....	....	....	....	....	....	.....	....	....	....	No data given on any class except cylinders.
15...	2.60	.55	.37	.10	.30	3.05	3.35	40	50	10	25500	2600	.15	170	
16...	2.65	.60	.22	.09	.45	3.15	3.60	43.3	51.7	5	22000	2400	.125	174	

TABLE 4—CRANKCASES

Number	Silicon	Manganese	Phosphorous	Sulphur	C. Carbon	G. Carbon	Total Carbon	Percent Pig Iron	Percent Remelt	Percent Steel	Tensile Strength Pounds per Sq. In.	Trans. Break 1¼ inch dia. Ar. Bar 12 Inch Centers	Deflection in Inches	Brinell Hardness	REMARKS
1...	2.30	.60	.40	.08	.40	2.80	3.20	.40	60	....	.....	.....	....	...	Same mixture as used for crankcases.
2...	2.50	.60	.55	.15	.45	3.10	3.55	35	40	25	40000	3100	.18	185	Same mixture used for all classes.
3...	2.25	.65	.20	.10	.40	3.00	3.40	34.3	45.7	20	30000	3000	.15	201	Same mixture used for cylinders and flywheels.
4...	2.20	.65	.30	.09	.20	3.30	3.50	45	45	10	34000	3800	.17	...	Same mixture used for all classes.
5...	2.65	.60	.22	.075	.25	3.30	3.55	61.6	33.4	5	.....	2200	.14	174	Same mixture as used for miscellaneous class.
6...	2.20	.65	.45	.09	.50	2.00	3.40	50	37.5	12.5	33000	3300	.12	217	Same as for cylinders.
7...	1.75	.55	.25	.08	....	....	....	50	30	20	33500	3350	.16	207	Same as for cylinders.
8...	2.40	.60	.60	.09	.35	3.10	3.45	56.25	6.25	37.5	21700	2800	.12	170	Same mixture used on flywheels and miscellaneous class.
9...	....	....	....	....	....	....	....	....	....	....	.....	....	....	....	No data given.
10...	2.10	.60	.20	.095	.60	....	....	56	32	12	.....	....	....	190	Same mixture used for all classes.
11...	....	....	....	....	....	....	....	....	....	....	.....	....	....	....	No data given.
12...	2.50	.65	.40	.08	.35	3.00	3.35	50	50	....	27000	2720	.10	180	Same as used for miscellaneous class.
13...	2.40	.65	.30	.095	.35	2.95	3.20	40	44	16	.....	....	....	165	Same as used for pistons and miscellaneous class
14...	.....	...	...	....	....	....	....	....	....	....	.....	....	....	...	No data given.
15...	....	....	....	....	....	....	....	....	....	....	.....	....	....	....	No data given.
16...	2.35	.60	.18	.09	.55	2.95	3.50	43.3	46.7	10	28000	3400	.187	196	Same mixture as used for pistons and miscellaneous class.

a 36-inch cupola with 2200 pounds of coke on the bed. The fuel ratios are not very different, No. 3 being 1 to 6.6 and No. 8 being 1 to 7.6. It would seem that No. 3 is melted lower than No. 8, which accounts to some extent for the difference in the carbon. As a rule castings in this class are not as complicated and variable in section as are cylinders and crank cases, and strength is not of primary importance. They can therefore stand being made softer and from a more fluid iron, with machining qualities given much more consideration. As said before, where possible, it is well to use the iron that gives the best results to the work at hand, and the composition and proportionment of the pig iron, remelt and steel is largely a matter of experience and judgment.

It is of interest to note that in No. 3 only 25 per cent of pig iron is used, which is the minimum in all the mixtures submitted. Oftentimes the ailments of defective castings are attributed to lack of sufficient pig iron in the mixture, but the writer is familiar with the foundry using this mixture, and the class of work turned out, and believes if it were not of proven value, it would not be submitted in the questionnaire. The experience of the writer has been that defects such as shrinks and draws have often been remedied by raising the percentage of pig iron when using less than 40 per cent pig iron, even though the analyses may be nearly identical in the two instances. For this class of work, the writer has used for a number of years a mixture of about the following composition:

	Per cent
Silicon	2.40-2.60
Manganese	.50- .70
Phosphorus	.25- .35
Sulphur	.06- .08
C. Carbon	.30- .40
G. Carbon	3.10-3.30
Pig Iron	about 40
Remelt	" 50-25
Steel	" 8-10

There is little to comment on in the data on crank cases in Table 4. Most of the foundries use either the cylinder iron or the softer iron used for small castings. None

use special iron for flywheels, but in most cases, use cylinder mixtures, especially where teeth are cut in the rim of the flywheels. The cupola practice is practically in very case a facsimile of that shown with the cylinder data.

To show the interest which some of the foundries manifested in data requested on the questionnaire, one large automobile corporation foundry submitted the ideal mixture as viewed by their metallurgist, foundry superintendent and assistant foundry superintendent. This data is all available for use should the association desire to appoint a committee to draft recommendations for the different classes of this work to serve the automotive engineer and manufacturer as a guide in writing specifications.

Discussion—Notes on Gray Iron for Automotive Casting

A. O. Backert.—This is a very interesting and a very valuable contribution to gray-iron practice. It represents the results of a very careful investigation made by a series of questionnaires, and the tendencies indicated are certainly interesting. Is there any discussion? Does anybody want to ask any questions?

R. S. McPherran.—I would like to ask if there was any relation to the total carbon content?

H. B. Swan.—I don't know how to answer that as we can't very well regulate the height of the tuyeres. I really don't see how that would be effective except that you would have a low or higher bed on the cupola.

E. J. Lowry.—The higher the tuyeres the higher the total carbon in the casting. That comes of the high coke bed.

H. B. Swan.—I think the speed of melting has something to do with that. Also the quality of the coke you use. It depends upon the structure and the total carbon of the coke.

Dr. Moldenke.—I think Mr. Swan mentioned a very interesting point when he speaks of the quality of the coke. That is the most important principle of the whole business. The only place where you can absorb is where the temperature is high. Some time ago I was in Kansas and I made some tests on practically 100 per cent steel mixtures. In this particular place they were melting scrap. The scrap was giving them good results. I tried with the small cupola to see if it was possible to melt steel complete, Now the experience that I had was if you try to melt steel in the cupola in the ordinary way you will get some carbon in it. It is the steel that draws the carbon from the fuel. I took the ordinary cupola of the right height and used about one-fourth or one-half of ordinary coke and the rest petroleum coke made in the refineries, which has 99 per cent carbon. I let it run two and one-half hours in the cupola, and it could have run all day long. It depended entirely upon the structure of the coke and the great amount of carbon in the coke. With a high temperature and a very high steel structure you have almost the carbon that you want to get into your steel. I think that is the solution of making pig iron out of steel. That is what I actually did an could repeat over and over again.

E. J. Lowry.—I think there are some factors entering into the carbon proportion tests. Take the 100 per cent steel scrap and put no silicon in and you will pick up more carbon. Neither will you pick up the amount of carbon in your steel scrap if you will have a low bed in comparison with a high bed.

Dr. R. Moldenke.—Mr. Swan states the cupola is a law unto itself. That is true. My own experience is that there is an absolute chance of standardizing cupola practice if we would only do it. The trouble is that we won't do it. The trouble is one man runs his cupola one way and another another way. Last week I was in Detroit. One cupola I saw had a tuyere area of 3 inches, and another had 7 inches. They were running a normal amount of iron in each of these cupolas. One of these was wrong. When Mr. Swan says the practice is about one to four, that may be in those cupolas that he has seen. As a matter of fact the relation is too large. A small cupola can have it

rather large, and a large cupola rather small in order to get the pressure up. My own experience is that standardization would be one to three for the small cupola; because you get the air running up the sides.

Chairman A. O. Backert.—Mr. Swan,—in increasing the wearing qualities and the hardness of your cylinders you stated that you had tests of one cylinder that ran over 50,000 miles that had not needed regrinding. Is this because of increased hardness, or have you solved that problem of grinding?

H. B. Swan.—The grinding wouldn't solve it because you have to machine your bores first. They are reamed and ground first. The accuracy with which that is done has a bearing on the cylinder block. As a rule a machine shop man could get up the hardness to two hundred.

Chairman A. O. Backert.—Did you get the Brinell hardness of that cylinder block that gave you 50,000?

H. B. Swan.—Yes. As I remember it, it ran 170 Brinnell. Of course we have to use special methods to get the hardness in the barrel due to the fact that the upper part of the barrel is the last part to cool. If you knock a cylinder casting out a short time after it is poured you can see that very effect. That part of the block is hot for a long period. In order to solve that to some extent we take the barrel of cores that make up a steel hollow with a cutting of one-fourth of an inch of sand. You have an opening through the bottom board and up through the entire mold which gives a circulation of air which allows it to cool.

Dr. Moldenke.—I would like to ask Mr. Swan one question. There are a number of reasons for the wear of a cylinder. One that I haven't noticed that you gave was the piston ring. If you have a very good result from your cylinder maybe it was the piston ring that did the wearing and not the cylinder.

H. B. Swan.—That of course is to be considered. You ought to have your piston ring softer than your bore because they are cheaper to replace than the cylinder block.

Visual Observation of Melting in a Cupola

By John Grennan, Ann Arbor, Michigan

It has been quite generally believed that in melting cast iron in a cupola, there is a rather limited section of the cupola in which melting takes place. This section is usually referred to as the melting zone. It is also a more or less accepted idea that the melting is fairly uniform in horizontal sections of the melting zone.

A. W. Belden presents the idea that the melting zone should be not lower than 19 inches above the tuyeres under the conditions with which he worked. He says "Experimental determination of this region is not necessary. In practice the bellying out of the lining of the cupola is a perfect index of the position of the melting zone, and this bellying is in the region where temperature is highest and oxygen is absent." This locates the lower limits of the melting zone quite satisfactorily.

Dr. Moldenke stated in a paper before this association at its convention at Rochester last year: "The only conclusion to be derived is that melting takes place much higher than is supposed along the lining." This leaves the top of the melting zone quite indefinite.

Method of Observing Melting

In order to watch the process of melting in the cupola at the University of Michigan holes were cut in the side of the cupola. The cupola is shown in cross section in Fig. 1. It is 30 inches in diameter inside the lining. The holes, six in number, with centers 6 inches apart, are placed in a vertical row with the bottom of the lowest hole 21 inches above the top of the tuyeres. There are four tuyeres, 3x12 inches. The charging door is 7 feet above the top of the tuyeres and 9 feet above

the bottom plate. The fan used is an American Blower Co. type P, No. 5, run at about 2400 R.P.M. The air volume measures about 1500 to 1600 cubic feet per minute.

It was found that the holes slagged over soon after melting began, when they were shaped up with the daubing clay used in daubing the cupola. To overcome this, a small clay crucible was placed in the hole so as to project about a half inch into the cupola beyond the lining. The abrasion of the descending stock kept the holes open. A window of mica was placed over

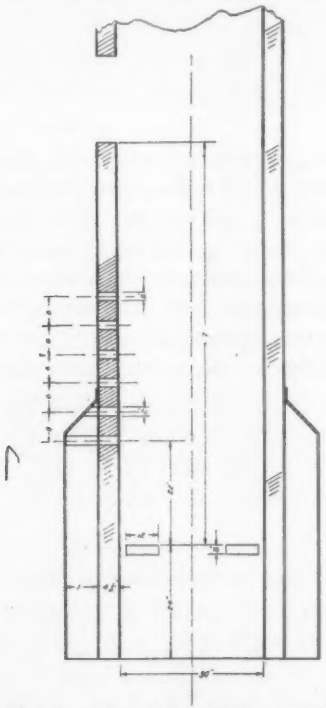

FIG. 1—ARRANGEMENT OF OBSERVATION HOLES THROUGH THE CUPOLA SHELL

the outer end of each hole to prevent the escape of hot gases. It was also found avisable to put in a sheet iron shutter to prevent smoke from covering the windows.

Method Followed in Charging

The following method was used in charging: the fire was started with wood and the bed charge of coke brought to 28 inches above the tuyeres. The iron charges weighed 700 pounds, 50 per cent pig and 50 per cent scrap or all scrap iron, with 75 pounds of coke between charges, (three to five charges to a heat).

The depth of the bed charge of coke brought it to the second hole. The depth of the iron charges varied from 7 inches to 18 inches, depending on the nature of the scrap iron. Light cored castings such as automobile cylinders, pistons, and gates increased the depth when compared to heavy flat scrap. The coke charges above the bed charge were estimated to be 6 inches deep. When measured they varied from 6 to 7 inches.

Pyrometer Used for Obtaining Temperature Data

An optical pyrometer was used to determine the temperature at the openings. There was considerable variation in the readings, due to lack of uniform conditions in the cupola. The temperature of the gas could not be taken. It was necessary to focus on a solid object and the size and contact with colder objects influenced the temperature of the piece. The readings were taken on the hottest piece of coke in view. Although the temperatures read were lower than the gas in the cupola at that point, they showed to quite an extent the rapid heating of the stock in the melting zone. The temperature readings were taken on the four holes just above the tuyeres. Table I is a typical record. Table II is an average for five heats.

TABLE I

Friday, August 4, 1922

Time	No. 1 Degrees Fahr.	No. 2 Degrees Fahr.	No. 3 Degrees Fahr.	No. 4 Degrees Fahr.
3:05	2782	2910	2515	2135
3:10	2862	2808	2285	2098
3:15	2782	2555	2560	1980
3:20	2790	2390	2429	2005
3:25	2738	2528	2502	2105
3:30	2905	2720	2703	2320
3:35	3085	3040	2860	2525

TABLE II

	No. 1 Degrees Fahr.	No. 2 Degrees Fahr.	No. 3 Degrees Fahr.	No. 4 Degrees Fahr.
Average Temperature	2800	2638	2370	2213
No. of Readings	40	37	41	20

The highest temperatures recorded were no doubt much nearer the real temperatures than the average temperatures. The higher the reading was taken in the cupola the less reliable the results, due to contact with colder objects and the shorter time exposed to the hot gases.

The temperatures taken showed that from 21 inches to 40 inches above the tuyeres, the gases were hot enough to heat small pieces of coke above the melting point of cast iron.

A base metal thermal couple was placed in the cupola at the charging door. The end of the couple was about a foot below the charging door so that the burning of the gases with the air at the charging door would not influence the temperature. As the length of time that charging kept the stock as high as the charging door was short, these temperatures could not be considered very reliable. The record showed a rapid increase from about 250 degrees Fahr. when the blast was put on to about 1575 degrees Fahr. eight minutes later. Table III gives the temperature records at the charging door for three heats.

TABLE III

Time	Temperature Degrees Fahr.	Time	Temperature Degrees Fahr.	Time	Temperature Degrees Fahr.
11:10	100	3:29	245	2:29	235
11:15	765	3:30	425	2:30	425
11:20	1465	3:33½	1175	2:33	1175
11:25	1405	3:35	1385	2:35	1360
		3:37½	1575	2:37	1575
		3:39	1545	2:39	1545
		3:40	1525	2:40	1325
		3:41	1505	2:41	1505

The temperatures taken gave little indication of what takes place in a cupola. It was possible by wearing smoked glasses to see a great deal of the process of melting in the cupola. As there is considerable space between the iron and coke as charged into a cupola, it was possible to see varying distances into the cupola. These distances varied from openings that reached to the center of the cupola or beyond to the complete closing off

of the opening by a piece of coke or slag. Notes were made of the conditions observed. The notes from any heat were always incomplete for several reasons, the chief ones being those given above. The experience gained in repeated observations made it possible to see more clearly what was going on.

Data on Observations

Melting was observed to extend from the lowest hole 21 inches above the tuyeres to the fifth hole 46 inches above the tuyeres. This was the widest range of melting that was observed. The heat consisted of three charges. The first charge was 50 per cent pig and 50 per cent scrap and weighed 700 pounds. It was 9 inches thick and on a 28 inch bed charge of coke. The second charge was 80 pounds of coke and 800 pounds of iron. The iron was medium weight and light scrap, consisting of shop pigs, gates and risers. The coke was 6 inches deep and the iron 11 inches deep. The third charge consisted of 80 pounds of coke and 800 pounds of light gates. The coke measured 7½ inches deep and the iron 17 inches. The blast was put on at 10:45 A. M. and the observations were made between 10:53 and 10:58 A. M. These are similar to a great many observations except that melting was not observed above the fourth hole in the other heats.

The following are the notes taken during this heat: The holes in the cupola were numbered from bottom to top. The time indicates beginning of observation.

10:53 Hole 1, Pig iron melting
2, Scrap iron melting
3, Coke and iron mixed. Iron melting
4, Coke and iron. Iron melting
5, Scrap iron melting
6, Coke red hot

10:58 Blast off
Hole 1, Scrap melting
2, Coke. Iron dripping down
3, Scrap iron melting
4, Coke and scrap iron, scrap iron red hot
5, Scrap iron dull red

11:04 Hole 1, Coke, iron dripping down from above
2, Coke, iron dripping down from above
3, Scrap iron melting
4, Scrap iron. Small pieces just beginning to melt
5, Top of scrap red hot

11:09 Hole 1, Scrap iron, all pieces melting
2, Scrap iron melting
3, Top of scrap red hot
11:11 Hole 1, Scrap iron melting
2, Scrap iron melting
11:13 Hole 1, Last of scrap melting
11:15 Blast Off—End of heat.

The following is another set of notes on observations made where the range of melting was not as wide as the one above.

The bed charge of coke measured 28 inches above the tuyeres. The bed charge of iron consisted of 700 pounds of iron, 50 per cent pig and 50 per cent medium weight scrap iron. The depth of the iron charge was 10 inches. The second charge consisted of 75 pounds of coke and 700 pounds of iron. The iron was 50 per cent pig and 50 per cent scrap, the same as the first charge. The third and fourth charges consisted of 75 pounds of coke and 700 pounds of medium and light scrap iron. The fifth charge consisted of 40 pounds of coke and 400 pounds medium weight scrap iron.

Blast on 3:02 P. M. Holes were numbered from bottom up.
Time
3:03 P. M. Hole 1, Coke.
2, Coke. Red hot pig in contact with coke.
3, Scrap dark red.
4, Scrap dark red.
5, Scrap.
6, Coke.
3:08 P. M. Hole 1, Coke.
2, Coke and melting pig.
3, Red hot scrap partly melting around side of cupola
4, Scrap red hot.
5, Coke.
6, Coke.
3:15 P. M. Hole 1, Iron dripping down thru coke.
2, Melting scrap and coke.
3, Melting scrap and coke.
4, Melting scrap.
5, Coke.
6, Iron red hot.
3:23 P. M. Hole 1, Coke.
2, Coke.
3, Coke and melting iron.
4, Melting iron.
5, Coke.
6, Scrap small pieces red hot.

3:30 P. M. Hole 1, Coke Iron dripping down from above.
2, Blocked with coke.
3, Scrap melting, outside melting faster than in center of cupola.
4, Coke and melting scrap.
5, Coke.
6, Coke.

3:40 P. M. Hole 1, Coke.
2, Coke and melting scrap.
3, Melting scrap.
4, Red hot scrap.
5, Red hot scrap.

3:47 P. M. Blast off.

The foregoing observations were made by students. A large number of similar observations were made some more complete in other details not given clearly in these reports. It was desired to get as accurate a statement of what was seen as possible, rather than an interpretation of what was taking place.

What Takes Place in the Cupola

Summing up reports and using his own notes, the writer can state definitely that the following occurs in the cupola under the conditions given:

Melting takes place as low as 21 inches above the tuyeres and extends to as high as 46 inches above them. The highest melting occurs at the lining and consists of the lightest scrap. The last pieces to melt are always at the center of the cupola and are the remains of the heavier pieces. Pig iron (machine cast was used) begins to melt near the lining about 34 inches above the tuyeres, the edges rounding off first. At 28 inches above the tuyeres, pig iron near the lining melts rapidly. The melting in the center is about 6 inches lower than at the lining, at the 22 inch and 28 inch level. An average sized piece of pig iron will take about six minutes to melt and will settle 6 or 8 inches in the cupola while melting.

The stock in the center of the cupola is visibly colder than at the lining. The higher in the cupola the greater is the difference in temperature between the stock at the center and the lining. Compact charges of iron, uniform in size, reduce the range of melting. There is considerable mixing of the coke and iron in their descent in the cupola.

Causes of Wide Range in Melting

The causes that contribute to the results may be worth considering. The wide range in melting is due to three or four conditions. One is the speed of the gases through the stock which carries heat high above the supposed melting zone. Another is the fact that the space between the coke at the lining is greater than in the center. This may be accounted for in two ways. The stock in descending shifts and adjusts itself more compactly in the center while the lining has a tendency to retard and open the stock. In throwing iron into the cupola, the blows pack the center more than at the lining. A third reason is the one given by A. W. Belden.* He shows that combustion in the cupola occurs below the surface of an inverted cone, which has its apex at the center of the cupola level with the bottom of the tuyeres and its base at the lining, 19 inches above the tuyeres. He gives as the probable line of highest temperature a modification of this cone with the apex cut off about half its height or 10 inches above the tuyeres at the center of the cupola. Another fact that would carry the heat higher at the lining is that the lining soon gets heated to a high temperature and ceases to absorb heat to any extent but reflects it back into the stock.

Conclusions

Judging from what was observed the following conclusions seem justified:

1. Upper tuyeres would tend to increase an undesirable condition in the cupola and should not be used. Upper tuyeres would increase the difference in temperature between the center of the cupola and the lining. A center tuyere, if practical, would be desirable.
2. Wide variations in either thickness or analysis in the pieces of metal charged should be avoided. Light scrap iron at the lining, may begin to melt 24 inches higher in the cupola than the last piece of pig of the same charge completes melting at the center. The light scrap of the second charge will be mixed with the charge below it or possibly the last iron of one charge to melt may be mixed with the first iron melting from the second charge above it. Iron in three charges is often

*Bulletin 54, Bureau of Mines, pp. 17, 18.

melting at one time. The use of ferro-manganese in the cupola, or high silicon pig iron, to raise these elements is likely to lead to variation in the analysis of the metal. If high silicon pig iron was used as a softener, and in one charge happened to be charged into the center of the cupola, and the next near the lining, it would melt at about the same time in both charges.

A receiving ladle with the capacity of at least one charge should be used. If the scrap iron is less in cross section than the pig iron, and this is usually true, a larger proportion of scrap will be found in the first tap than is representative of the first charge. This is no doubt partly responsible for the general opinion that the first tap is inferior to the others.

3. Coke of uniform size should be used. This will prevent possible raising and lowering of the melting zone.
4. The height of the charging door in the cupola used is too low. Considerable more heat could be absorbed from the gases. An increase in the height of the charging door would increase the height of melting at the lining slightly but it is doubtful if it would offset the advantages gained.

It is no doubt possible to improve the quality and uniformity of cupola melted cast iron by a further study of the process of melting in the cupola.

Discussion—Visual Observation of Melting in a Cupola.

Chairman A. O. Backert.—This is certainly a very interesting paper, and I think it is of more vital importance to the foundrymen than any other that has been discussed this morning.

Mr. Thunin.—I would like to compliment Mr. Grennan on the paper he has just read, primarily because of its originality. Mr. Swan said in the early part of the discussion that with the foundrymen asking questions a healthy condition is shown. I believe we all ought to use our heads on these ques-

tions. The sulphur point is an important point, and another important point is the combustibility of coke. I think there has been more foolishness written about that than any other subject.

J. D. Stoddard.—There is just another point, and that is the importance of the uniformity of charge operations. By uniformity you can often offset this factor as shown by this paper. In order to get uniformity it is important that some means be provided so that a reservoir be maintained throughout the heat.

F. E. Hull.—I would like to raise just one point of caution in attaching too much importance to observations made in a 30-inch cupola as compared with cupolas of normal size as used today. A 30-inch cupola is rather a small size. Several years ago the firm with which I am connected established a small cupola in which we made a number of experiments and we found that the cupola practice developed in that small cupola could not be developed in a large cupola.

J. D. Stoddard.—I was interested in the remarks of Mr. Hull regarding uniformity of iron. I would like to inquire what quantity of molten iron was being used. He spoke of a mixing ladle of 1500 pounds, which would be rather small in a cupola of 8000 pounds.

F. E. Hull.—In regard to that I would say this was on the continuous melting cupola, and the load of iron in the cupola was constantly changing. There were times when there was very little iron in the cupola, the aim was to keep the iron low in the cupola. It varied perhaps from a ton to three tons.

Centrifugal Casting

By L. CAMMEN, New York City

Centrifugal casting of metals is an old art, but did not assume commercial importance until about the time of the World War. Since then, however, its progress has been very rapid, largely because of a better understanding of the art of casting metals generally and development of materials that can be used for permanent molds.

In this country it has powerfully affected the development of several industries. In the field of railroad car wheel manufacture the American Steel Foundries developed large scale production of the Davis wheel. The Sandusky Foundry & Machine Co. has for several years been successfully making bronze propeller sleeves and paper mill rolls and have developed the art of casting to the point where they can make large diameter tubes up to 26 ft. long.

The U. S. Cast Iron Pipe & Foundry Co. has gone into the manufacture of centrifugally cast-iron pipe on a big scale with the result that it would not be an exaggeration to say that sand-cast cast-iron pipe is doomed. Of late centrifugal casting has acquired a further importance through the development of a method by which tubes and plate can be cast in such metals as Monel and alloy steel, and there are already several plants which are preparing to place on the market Monel metal seamless tubing, tubing of high-temperature alloys with chrome-iron base, bronze bushings and even standard steel pipe and plate.

Finally, a method has been found to apply centrifugal casting to the production of ingots from tool bits to 16-inch ingots, which promises to spread the process through the entire steel industry.

Mechanics of Centrifugal Casting

As regards the mechanics of centrifugal casting, the choice lies between casting on a horizontal axis, on a vertical axis

and on an inclined axis. When a material is cast on a horizontal axis and the axis of the object is coincident with the axis of rotation, a perfect cylinder is obtained. If the axis of the object does not coincide with the axis of rotation, a centrifugal cylinder is obtained with the walls of the casting thicker at the one side and thinner at the other side. These may prove useful in casting such objects as piston rings. In casting on a vertical axis the external surface of the casting follows, of course, the shape of the mold, while the interior is a paraboloid of revolutions.

Casting on a vertical axis may be used for short objects, in particular, such as gun shells. In casting on an inclined axis the exterior face of the object follows the shape of the mold, while the interior is a very elongated paraboloid of revolution, the shape of which depends on the angle of inclination of the machine and the speed of rotation. Such casting on an inclined axis has been employed for more than 30 years in making long tubes where the metal would not spread sufficiently fast on a horizontal axis and where it does not matter if the internal shape of the tube is not concentric with the external shape (for example, where the casting is subjected to subsequent machining.) Casting on a horizontal axis is one that will particularly interest the ordinary foundryman, as the great majority of the work he may have to do will be of this character.

Temperature of Molds

A more important distinction deals with the temperature of the mold. In this, there are again three classes of casting which may be enumerated as castings on a warm mold, a water-cooled mold, and a hot mold. The question which mold to use depends exclusively on the size and kind of casting and the metal therein. The simplest and easiest to use, of course, is the warm mold, as it requires neither special heating nor special cooling. Warm molds may be either permanent and made in cast iron or alloy steels, or they may be clay lined. The question is merely whether metal will properly spread in such a mold and whether it will make a good casting. This is a point which must be very clearly understood as it lies at the

foundation of all centrifugal casting work and will, therefore, be explained in some detail.

Assume that we have to make two steel castings: One 12-inch outside diameter, 9 inches inside diameter and 36 inches long, and the other, 4 inches outside diameter, 3 inches inside diameter, and 8 feet long. The first casting will weigh roughly 500 pounds and is 3 feet long, the second will weigh 150 pounds and is 8 feet long. It will be clear to a practical foundrymen that whereas in the first case the metal under the action of centrifugal force will spread through the short mold before it has time to chill; in the second case it is practically certain that the metal will not spread through the narrow, long mold and that it will chill long before it reaches the end of the mold, assuming, of course, that in both cases the mold is only warm, which means, say, not in excess of 600 degrees Fahr. It is obvious, therefore, that in the first case, a warm mold may be used with comparative safety; in the second case some other arrangement would have to be made. An effort to meet this situation was made by the use of either movable spouts or trough-like arrangements in which the whole metal was poured in at once over the entire length of the mold. While certain success in cast iron has been attained with movable spout, the trough, though nearly 40 years old, has not yet been developed to a successful conclusion.

The difficulty of properly distributing the material in a warm mold led to the development of two other methods diametrically opposed in their principle, namely, the water-cooled mold (DeLavaud) and the hot mold (Cammen.)

The water-cooled mold has so far been successfully used only in the manufacture of cast-iron pipe. It is obvious that metal projected against a water-cooled mold will chill instantly and, therefore, cannot be expected to spread under the action of centrifugal force. Therefore, either the spout or the mold has to move, and, as a matter of fact, both have been attempted. In the early DeLavaud machines the spout moves, projecting a measured stream of cast iron which impinges on the walls of the mold, is flattened into a ribbon under the action of centrifugal force, and welds on to the layer just pre-

ceding it. In the later DeLavaud machine the stream of water that cools the mold is used to rotate it and move it longitudinally with respect to the spout which is stationary, so that by the time the casting is completed, the mold has moved out over the spout and is ready for the extraction of the cast pipe. The process requires extreme care in the design of machinery, but with properly designed machinery is comparatively easy to operate.

One element, however, in connection with cold-mold centrifugal casting has to very clearly borne in mind, and that is, that cast iron projected against a water-cooled mold gives a highly degraphitized metal, or a hard, brittle, white iron. This can by proper annealing be converted into gray iron of a high strength, and, in fact, tests have shown that centrifugally cast cast-iron pipe is on an average at least 20 per cent stronger than sand cast, and claims are being made to its being even 40 per cent stronger. The annealing of certrifugally cast cast-iron pipe has been very successfully carried out on a small scale, but what will be its cost when carried on on a large scale, say 1000 tons a day in a single plant, is a question that only time can answer. It should be very clearly understood that no doubt is expressed as to the possibility of doing it. With modern furnaces and pyrometer control there is no question that it can be done—at a price, but what the price will be, and in particular what the waste in overheated and underheated castings, is a matter that only time can show. From our general knowledge of operations of this character it would appear that unless methods of annealing are radically different than those of today, the waste of castings would be of an order of 15 per cent which might go a long way towards offsetting the economic advantages of the new process.

The third process is that of hot-mold centrifugal casting, the interest of which lies in the fact that it permits to produce thin sections, say, 3/16 inch and up, in considerable lengths and in comparatively small diameters. To understand this process it would be remembered that if a liquid, such as oil or mercury be poured at one end into a rapidly rotating horizontal tube or mold, it will spread from end to end under the in-

fluence of centrifugal force and form a uniform tube. In casting metals the question of time arises, however. A molten metal will spread in exactly the same way as oil or mercury, providing it stays liquid long enough, and the trouble with the majority of metals is that they are poured at temperatures only a little above their melting point, and, therefore, chill with extreme rapidity. To obviate this the mold may be heated to a high temperature which, in this case, means, say, 1700 degrees Fahr. for steel or monel metal, 1500 degrees for brass, 1200 degrees for aluminum, and so on, up and down the line. When steel is poured against a mold having a temperature of 1700 to 1800 degrees it does not cool instantly as it would on coming in contact with the cold mold. In fact, it has been found that a 3/16-inch wall takes about 45 seconds to harden completely, which is sufficient to produce clean metal. It has been found that actually tubes 3½ inches outside diameter, ¼-inch wall and 6 feet long can be produced in hot molds without any difficulty.

There have been numberless attempts to produce by centrifugal casting discontinuous surfaces such as ingots, in particular small ingots, for example; tool bits, plate and gears with the teeth cast in. Single gears, both spur and worm gears, have been successfully produced in molds rotating on a vertical axis, the metal being poured at what would correspond to the hub of a wheel, and it may be stated, in this connection, that in order to make a successful gear casting, it is necessary to pour a very heavy hub which acts as a feeder to the rest and has to be removed later on. All attempts to cast such articles on a horizontal axis have, however, failed until lately. Gears and ingots have been actually produced centrifugally by cutting what corresponds to teeth in the mold, but the metal in such castings was very poor and in particular full of "cold shot." The reason for this is rather easy to see. When molten metal coming from the spout strikes the projections in the mold, it is started in a fan spray which instantly chills in the air and is later on incorporated as cold shot into the casting. This difficulty has been overcome, however, recently by the use

of a "bottle-neck" mold which has been described in the technical press.

Patent Situation

The designer of machinery for centrifugal casting should make himself fully acquainted in the patent situation. As stated above, the art of centrifugal casting is old and the majority of the basic features in the design of machinery and in the processes themselves are now free to everybody from a patent point of view. In fact the shanks machined for making cast iron pipe centrifugally, described in the *Scientific American* of Dec. 1, 1849, do not essentially differ in any way from the great majority of machines working with the cold mold at the present day. At the same time, however, there are a number of patents on minor improvements which are still valid, and any designer not familiar with what is and is not valid may either infringe on the right of someone else or let himself be bluffed by unfounded claims.

The feature of temperature control of the mold is, however, new and both the water-cooled mold and the hot mold are covered by patents which are from all indications valid and of sufficiently recent date to be fully alive.

Field for Centrifugal Casting

The field of centrifugal casting that may be of interest to the foundryman is very large, though, of course, materially affected by the foundry equipment already available and the location of the foundry. Practically any cylindrical body can be made by centrifugal casting in cast iron, steel or nonferrous materials. Where the work of a foundry is seasonal it may pay to have one or more centrifugal casting machines installed and make pipe in slack times. The cost of casting machine is comparatively small and there is always a market for either cast iron or steel pipe, especially in sections at some distance from the big sources of supply of these materials. Steel rings may also be easily cast by this process.

It should be remembered also, however, that while the principle of centrifugal casting is extremely simple, good results can be obtained only when everything is just right. It

should be remembered clearly that all claims as to centrifugal force, "fluid pressure" and so on, producing better metal, are based on a misunderstanding of the process. The pressure due to centrifugal force produced by the rotation of the mold is far too low to affect the composition of the metal, and it is the rate of cooling rather than the whirling of the metal that produces the remarkable result obtained by centrifugal casting. By centrifugal casting, metal far superior to anything in sand casting can be produced, but to get such results it is necessary in the first place that the metal as it comes from the ladle should be right. There is an impression that slag, scum or dirt can be separated by centrifugation out of metal in the same way as butter is separated out of cream. This is true only to a very slight extent. If the metal could be kept fluid very long, say, several minutes, segregation of the lighter particles would probably take place. Actually, however, the viscosity of molten metal is entirely too high and it chills too quickly, even in hot molds, to produce reliable separation of slag and dirt, although some takes place. In water-cooled molds the chilling of the metal is practically instantaneous and there is no segregation at all. It is, therefore, particularly important to have clean metal, whether it be cast iron or steel, brass or bronze.

Another element which has to be closely watched is that the metal should be at the right temperature. Excessively cold metal will not form good pipe, while excessively hot metal is apt to show up in the casting as blistery or frothy.

The next requirement without which success is impossible is the proper design of the machine itself and the proper layout of the work. In principle a centrifugal casting machine is extremely simple. It is nothing but a mold rotated at a rapid rate and a spout to supply the metal. Where warm molds are used, all that is necessary is to make the whole structure extremely strong so as to prevent vibrations and distortion under the great centrifugal stresses used. While this sounds very simple those who have designed such machinery will agree with me that it is by no means quite so easy to accomplish in practice as it looks on paper. It should also be

clearly realized where a clay lining is used that outlets should be provided for the gases generated in the core under the action of the molten metal. The clay lining, no matter how solidly baked, will contain a certain amount of air. When the molten metal strikes it, the air expands from the heat and unless another outlet is provided for, it makes its way through the molten metal, causing in it peculiar pin holes having the shape of tiny inverted cones. Another trouble with clay lined molds is their ability to accumulate moisture, which also expands from the heat of the molten metal and forms steam, and this results in another series of pin holes somewhat but not quite similar to those produced by the expanding air. The best way to obviate the formation of these pin holes is by keeping the lining hot enough to prevent any moisture content which means not less than 600 degrees Fahr. and providing for venting of the clay lining which can be done by drilling numerous small holes in the shell containing the clay lining. Just a few holes will not do, and at least 5 per cent of the surface of the shell should be drilled out in small holes.

Nonferrous Castings

Where bronze or brass are cast centrifugally, it is well to bear in mind two facts. The first is that these metals contract very powerfully on cooling, and therefore, draw away rapidly from the mold, and the second, that below their point of solidification they pass through a range of temperatures where the metal is quite brittle. If you bear in mind these two facts, you will easily see what may happen to a casting, especially of fairly large diameter and heavy wall. As it cools it draws away from the mold and, therefore, is not supported against centrifugal forces by leaning against the mold. Centrifugal force produces in the cast cylinder a stress of the same character as hydrostatic pressure, tending to rip the casting apart longitudinally, and this tendency is facilitated by the brittleness of the metal. Those who have made brass or bronze castings know how often they come out split lengthwise. The proper way to obviate this is by watching the casting carefully and stopping the spinning as early as possible, the idea be-

ing to stop it just as the metal has solidified sufficiently to maintain its cylindrical shape.

In casting aluminum the same situation exists with the exception that aluminum is not quite as brittle. On the other hand, molds for centrifugally cast aluminum have to be rotated at a higher speed, because of the lower specific gravity of the metal, which means that they have to be built far more substantially than brass or bronze casting molds.

The Molds

As regards molds for centrifugal casting, cast iron may be used for warm molds but it should not be used under any conditions either for water-cooled or for hot molds, and even for warm molds its use is not recommended unless the molds are very short, not in excess of 12 inches or very thick. A cast-iron casting is at best a somewhat uncertain proposition and there are apt to be planes of weakness. In centrifugal casting very high stresses are induced in the mold mechanically and especially thermally, and the combination of the two makes the use of cast-iron molds a dangerous and uncertain proposition.

In warm molds steel, especially steel pipe, may be used with fair safety and its life will be fairly long where the clay-lined mold is used. Where the metal comes in direct contact with the mold in warm or water-cooled molds there is no objection to the use of ordinary steel from the point of view of safety but there is a danger that the life of the mold will be very short. An excellent material for use in molds is of the following composition: Carbon 0.5 per cent; chromium, 26 to 28 per cent; silicon, 0.4 to 0.6 per cent and manganese, 0.6 per cent. This is known as the Becket metal and has been developed in the laboratories of the Electrometallurgical Corporation. If the mold, after casting, is to be subjected to machining, it is important to keep the carbon below 0.5 per cent. Where conditions are such that no machining is expected or only a little of it, the carbon content may be increased, the higher the carbon content the cheaper per pound the casting but the more difficult the machining. The mechanical strength of the material is not affected materially with

the increase of carbon up to 2 per cent and the price is lowered considerably by this. For hot molds the Becket metal would appear to be the most suitable.

Pouring Temperature of the Metal

The rate of pouring of the metal is an important consideration except where movable spouts or movable molds are used, in which case the size of the nozzle governs the rate of pouring automatically. Excessively fast pouring is decidedly harmful and usually the best results are obtained with the slowest pouring consistent with good delivery from the ladle (this is particularly important in large castings where the bottom-pouring ladle is used) and good distribution of metal in the mold. It is also very important, as has been stated above, to keep the metal at the right temperature, the temperature of the metal having a good deal to do with the rate of pouring in that a hotter metal can be poured slower than comparatively cold metal.

Pouring Spouts

Where stationary spouts are used it is a good plan to have the spout hot and it is very important to have it clean. In our own practice dealing with hot-mold pouring a short spout is used projecting into the mold for a distance of about 6 inches. We have adopted the following procedure which has given good results: The spout is shaped somewhat like a corn-cob pipe, the tobacco bowl corresponding to the end receiving the metal from the ladle, and the stem the delivery end. We make a two-part wooden box and embed the spout into it, filling the rest of the space with fireclay so that only a few inches of the spout project. At the bottom of the box are placed projecting through the wood, two strips of steel ⅛ inch by 2 inches by the length of the box. The whole business is then put into an oven and baked hard, the wooden frame being, of course, burned away in the process.

The gas or oil torch is then set into the large end of the spout and kept there for the time while the spout was not in use. On the platform in front of the mold are bolted on two strips of steel with slots corresponding to the strips of metal

embedded in the spout block. By the time we are ready for pouring, the spout is white hot and all we have to do is to push it along the slots until the delivery end projects a proper distance into the mold, remove the torch or the metal, pull it back into its initial place and stick the torch in again. We have found that there are no skulls in the spout even when such metals as high-carbon chrome or high-speed tool steel are poured and the spout is not affected by the vibration communicated to it by the mold.

Foundations

In all designs of centrifugal casting machines the greatest attention should be paid to making the foundations and all parts of the machinery ample from the point of view of strength and rigidity. The question of first cost should be given only the most moderate importance and the best materials should be used throughout, not only because the rupture of a machine may cause considerable damage to life and property but also because it will prove cheaper in the end. The stresses induced in the operation of a centrifugal casting machine on the machine itself and its foundations are so great that only the best materials will stand up. The writer has seen a case where a small centrifugal casting machine was set up without even being bolted to the floor, but simply held down by weights. He would dislike to be around the place with the machine in operation.

The best practice is to put a concrete foundation, preferably of the monolithic type, with substantial floor bolts having a shearing strength not less than ten times the maximum centrifugal stress on the machine. The frame of the machine should under no conditions be made of cast iron except the bottom plate, the side and upper members being of either steel castings or substantial rolled steel members.

Centrifugal casting may be made very profitable and is so simple that it can be carried on with unskilled labor with only one skilled man, who is usually the teemer, to supervise but under no conditions will it pay to use unskilled engineering labor in the design and installation of the machine.

There is an old saying current among molders to the effect that a lie in sand will be shown up in the metal. The same applies with still greater force to centrifugal casting, which is a process peculiarly impossible to be worked either by slipshod methods or on a shoestring, i. e., skimping on the quality of materials and on factors of safety in the design of machinery.

Discussion—Centrifugal Casting

N. K. B. Patch.—I would like to ask what type of metal you found best for permanent molds for bronze centrifugal casting. We have done some centrifugal casting work in bronze, and the molds have been fair.

L. Cammen.—For bronze, I might mention one point and that is this. In no case where you are using a permanent mold should you get the metal against thin metal. You have to give the mold some kind of protection to prevent the metal of the casting from welding to the metal of the mold. A thin sheet of castor oil applied just before the mold is heated gives very good protection. Some use cylinder oil. Any oil will do, providing it is applied in a thin enough scale.

Whenever you are dealing with problems containing metals you are up against a problem of this kind. If you cast your metal at a real high temperature so as to make it very fluid you have a sort of metal particles flying off. It is something in between atomic bombardment and molecular action. You have to cast them at the lowest temperature that you can at this particular size to distribute itself in the mold. I believe then you will find no trouble with either ni-chrome or chromium or high-chrome alloys. I want to emphasize again that the life of your mold will primarily depend on the temperature at which you pour your metal.

N. K. B. Patch.—We have found that burnishing or otherwise changing the flow of the water as the metal travels along is very essential in allowing the metal to lay quietly. That is affected by a thin sheet of cylinder oil, or whatever is used there. I was particularly interested in your mentioning the burnishing of the inside of the mold because that checked our experience a little bit along that line.

Mr. Hall.—I would like to ask Mr. Cammen whether in discussing the material for molds the alloy known as envoil has been considered due to the fact that it has a very low contraction.

L. Cammen.—All of these alloys contain nickel around 35 per cent. In the first place the coefficient of expansion is very close to zero. Above that there is quite a noticeable coefficient of expansion. The second point is that they are very unsuitable.

W. C. Landes.—I would like to ask a few words about the proper speeds in which to rotate on the molds, and also the angle of inclination. Whether a vertical casting is practical in lengths of about 10 inches.

L. Cammen.—As regards the speeds, this is a matter that has to be determined for each metal. In general there is no advantage, and with metals like bronze or brass there is a serious disadvantage of overrunning the necessary speed. In steel and steel alloys you can use a much higher rotational speed. For cast iron 1550; for aluminum, etc., 2250.

Now as regards the selection between the vertical and inclined and horizontal: With the vertical mold you get the outside shape the same as the mold; the casting is a paraboloid. Now it depends on what you want to make. If you want to make a short casting—say 10 inches long—all fairly large diameter, say about 8½ inches—you can do it in the vertical casting, providing you machine out the inside afterwards. If you have a large number of such pieces it is much cheaper and simpler to do it on the horizontal, using a mold 16 feet long. There are cases where you need an inclined axis. If you are casting a long piece of small diameter in a cold mold or long mold, your metal

will not distribute itself through the mold. If you use an inclined axis, you can pour your metal in while the mold is not spinning fast. Professor Lawrence, in his book on technical hydraulics, gives the complete formula for an inclined mold, especially for speed and inclinations.

Now as for the horizontal, it is probably the most usual way of casting as well as the most simple way. You can cast almost anything you want to in length.

E. J. Lowry.—Have you experienced any trouble with the warping of the molds?

L. Cammen.—We experienced this in split molds. In split molds we found a good deal of warping, simply because the inside of the mold chilled more rapidly than the outside. In solid molds I found nothing of this kind, whatever. The mold will warp, if at all, right in the furnace. If your furnace is designed right, there will be practically no trouble from warping. In special molds that is a different proposition. We have had a good deal of trouble from warping.

In the cold mold you can use the ordinary construction. In the ordinary construction you have the mold held simply at two ends. Now you can't do it with the hot mold, because the mold with 1800 degrees Fahr. is so weak ordinarily that it would bulge out. Therefore, a special construction has been given in which the mold is supported at the entire length of it. Now that is important. When you design your machine you have to consider the fact that your metal is carried off at the points where the mold is supported. If your mold is supported at these two or three spots you will have two or three chances that the mold will warp. If you want to prevent warping, design your mold uniformly with a generous area for the heat transmission.

Centrifugal Casting of Iron Piston Rings

By John A. Rathbone, Detroit, Michigan

Centrifugal casting really divides itself into a great many factors, but primarily it gives two principal advantages: First by utilizing the centrifugal force to obtain a greater pressure on the metal as it solidifies; and, second, it forms the casting without a core on the inside. In this article the writer will take up only the methods and their application as he is familiar with them. There are undoubtedly many devices and schemes with which he is not familiar.

The writer's first experience with centrifugal castings was with the Wasson Piston Ring Company, where he was called upon to make their piston ring pots. We first experimented with a pot about 6 inches long and 5 inches in diameter, casting it in a solid iron mold, revolving on the end of the emery wheel spindle, using a cap to determine the inside diameter of the casting. Of course this mold revolved on a horizontal axis.

We made a number of castings with this rig, our object being to make castings that were soft enough without having to anneal them. With the body of metal we had around the castings, and with the removable cap being held on with bolts, we could not work the machine fast enough to keep the metal from chilling. We even went to the expedient of heating the mold with a gas jet, before pouring in our metal. With this method we got the mold so hot that it melted out the bearings of the emery wheel spindle, but it nevertheless still chilled the castings.

From our experience with the solid iron mold, I conceived the idea of lining this mold with a refractory substance and therefore introduced into this mold some dry sand cores and made individually cast rings. This made some very excellent castings. We, however, could not see any possible economy in

this method, especially with the rig we had for pouring the metal, and the conveniences we had for rapidly taking out these cores and the castings.

Use of Cores

I then conceived the idea of making large rings centrifugally, the Wasson company then having an order for 4000 twenty-two-inch rings. A machine was therefore rigged up which re-

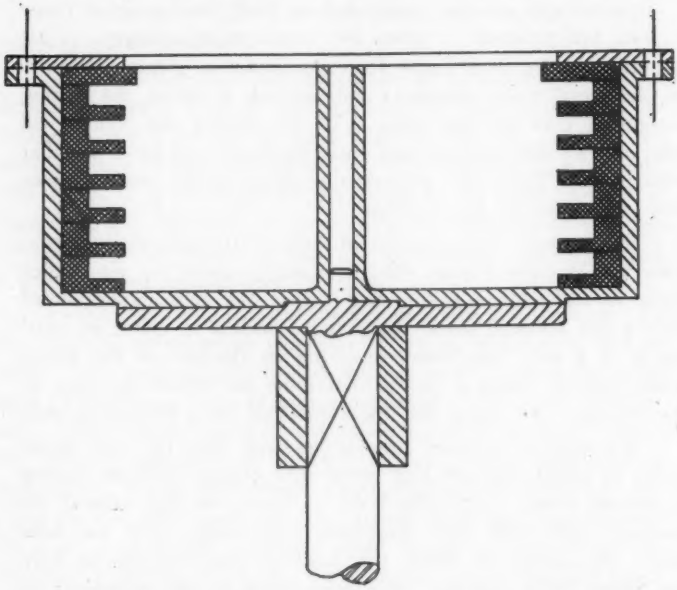

FIG. 1—MOLD FOR LARGE PISTON RINGS, SHOWING DRY SAND CORES SET INTO ROUND FLASK. CORES OPEN ON INSIDE PERMITTED INSIDE EDGE OF CASTING TO COOL TOO QUICKLY

volved on a vertical axis, using a machined round flask, as illustrated in Fig. 1. Into this flask cores were set.

To make economical core manufacture, these cores were made in six sections, and simply laid into the round flask, six rings being put in each flask. The bottom of this flask had to be lined with a cupola daub mixture, to prevent the iron

chilling when poured into it. The flask was revolved at about 300 revolutions per minute. This produced very perfect castings, so far as the exterior was concerned. We, however, ran into a very peculiar difficulty. The inside edge of the casting, not being covered, and therefore exposed to radiation, chilled more rapidly than the interior of the ring. The other three sides of the casting were next to cores and did not chill quite as quickly. The centrifugal action on the iron separated the grain of the iron just under the surface, and gave minute shrink holes. Of course, the machine shop called them "dirt," but under the microscope it showed up very distinctly as shrinks. This necessitated making the core completely surround the casting, and filling the mold through the horizontal gates into it, as illustrated by the drawing of Fig. 2.

This method was found to entirely do away with the shrinks and gave a casting about 25 per cent stronger than with the ordinary method of molding, and saved tremendously in floor space, as we were really getting six castings on the floor space of one. It also saved the ramming up of a large amount of green sand that we would have had to have used in case we had made them on the floor in green sand molds.

Subsequently, we made castings centrifugally, which ran from 8 to 30 inches in diameter, proving to be a great economy in both labor and floor space. It may be said, incidentally, that we poured these castings from crucible iron, which, of course, gave us an additional 25 per cent stronger metal, making the whole casting about 50 per cent stronger than ordinary cupola iron poured in the usual way.

Mr. Wasson, in the meantime, became interested in the DeLavaud method of casting piston rings. This machine revolved on a horizontal axis, the rings being cast in a built-up, permanent mold, using a series of steel rings to separate the castings. Of course, the metal had to be introduced into the revolving head with a trough, which was filled with iron, then slid into the mold, and dumped over to fill the grooves for the rings.

Without going into the details of this construction, I will simply mention the difficulty which we got into. These castings

came absolutely hard, and we then annealed them. The annealing process precipitating the combined carbon out of the casting, the carbon came down as temper carbon, and not as graphitic carbon. We machined up some of these rings, and

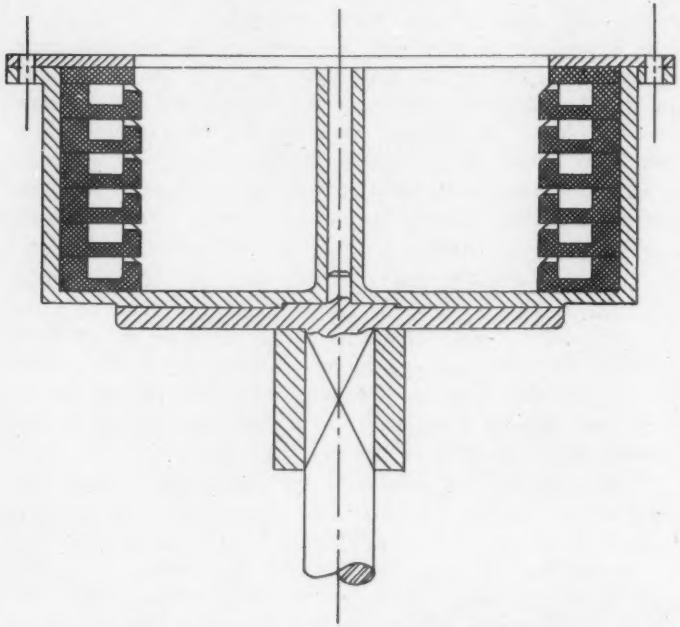

FIG. 2—SHOWING TYPE OF CORES WITH CLOSED INSIDE EDGES TO PREVENT SHRINKAGE TROUBLE CAUSED BY QUICK COOLING OF CENTRIFUGAL CAST PISTON RINGS

probably produced as perfect a ring as was ever manufactured. They checked absolutely perfectly for their tension, roundness, and all micrometer dimensions.

Carbon Precipitated as Temper Carbon on Annealing

These rings were put in an aircraft engine, and the engine run for 54 hours. The engine started off with the highest efficiency that it had ever shown, but the efficiency very soon fell, and at the end of 54 hours the rings had lost twenty

thousandths of an inch on the wall, and the cylinders were cut all to pieces. In other words, the casting which was made hard, and subsequently annealed, precipitated the carbon as temper carbon, which is the same as in malleable iron, instead of graphitic carbon, which is the form in gray cast iron. This ruined the casting as a bearing metal. In fact, the writer did a lot of experimenting, to determine whether there was any method of bringing this carbon down as graphitic carbon, and not as temper carbon.

Among my experiments I actually melted the casting, which was chilled and then annealed, and produced temper carbon, and maintained it in a melted condition for two minutes. Subsequently the metal being cooled and examined under the microscope, it was found that the carbon was still in the temper carbon form, instead of the graphitic. It was found that it had to be melted three minutes before the carbon re-dissolved in the iron, and, on slow cooling, came down as graphitic carbon.

We had no method of determining the tensile strength of these castings after they were annealed, as our castings came in very small sections. But it was quite evident that the casting with the carbon in the temper carbon form was stronger than the ordinary cast iron. This convinced the writer that, although this metal, which was really a cross between a cast iron and a malleable iron, was not suitable for piston rings, or any purpose requiring it to withstand friction, but that there was a large field for this individual metal. I therefore took the question up with a concern for centrifugally making their boiler nipples.

Annealed Metal Proves Excellent for Pipe Nipples

To accomplish this economically, I went to a 45 degree angle for the revolving head, as illustrated by the drawing of Fig. 3. With a horizontal head we had the difficulty of pouring in the metal, it being necessary to use a runner or trough of some kind. With the vertical head, we had gravity to figure as against the centrifugal force, and it gave a slight draft to the inside of the casting. At 45 degrees this draft

became practically nothing, and as I stated before, it could be poured very simply, directly from the ladle. We used a water-cooled head.

With this machine we poured as high as 80 castings per hour on a nipple one and five-eighth inches deep and five and three-quarter inches in diameter. Of course this iron came

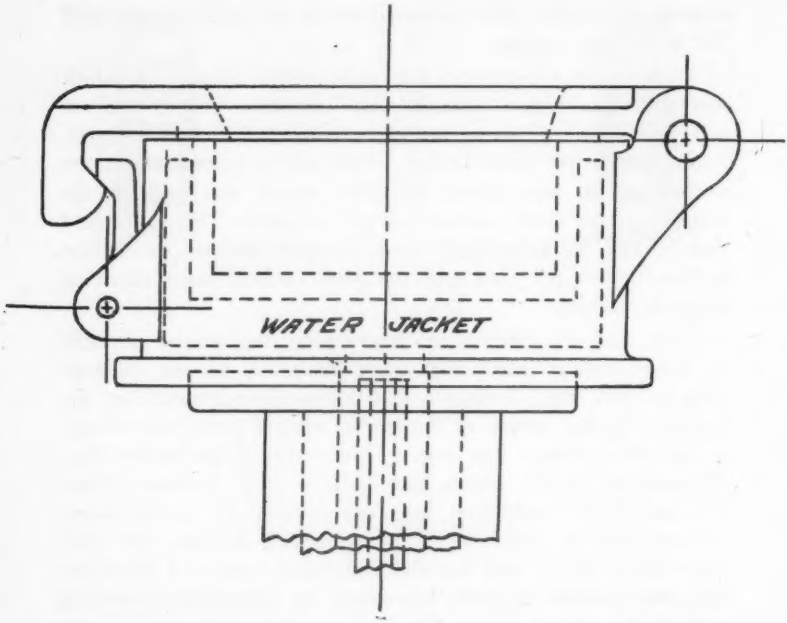

FIG. 3—PIPE NIPPLE MOLD INCLINED AT AN ANGLE OF 45 DEGREES TO FACILITATE POURING

hard, and was subsequently annealed. It produced a casting 65 per cent stronger than the ordinary sand made casting.

Economy in making castings by this method is entirely dependent on the diameter of the castings and the cost of replacing the molds. The limit in diameter is from two to three inches. When you are below that, a man can produce more castings in a snap flask than a man can pour off in a

revolving head; but above two or three inches, you cut out all the molding and simply have the pouring operation.

With a cast iron head it begins to show cracks for the first one hundred molds, but is suitable for use up to five or six hundred molds.

This method of casting would be entirely suitable for any round work, running from one and one-half to 12 or 14 inches in length and from 2 to 3 inches in diameter. With the increased length of the casting it would be necessary to decrease the angle at which the spindle revolved. It must be remembered that a casting made in a chill and then annealed, is no good for bearing metal. For such work as piston rings, or cylinder liners, it would be necessary to line this mold with cores.

Centrifugal Casting of Copper Shell Rings

There are a number of other angles to the centrifugal proposition. George C. Clark, during the war, made copper shell rings centrifugally, which ran from 12 to 14 inches in diameter. He discovered a very interesting proposition, and that was to knurl the inside of the permanent mold, so that the metal, in contact with this mold, would start revolving very rapidly. The subsequent metal would revolve a little slower, and of course the inside metal would take up the motion decidedly slower. This had the effect of rolling the metal, and he was able to get a tensile strength away above what he could get with a smooth inside surface, and, of course, very much stronger than he could get without a centrifugal action. He made a large number of the shell rings for the navy.

English Practice

The English have made both piston rings and piston linings, centrifugally. They depend on a very soft iron, which does not chill quickly, to obtain a soft enough casting. I really doubt whether their method would be economical in this country. Their labor conditions are entirely different. They get very fine, smooth castings for their heads, and do not water-cool them, throwing away the first two or thee castings

they make in the head, because they are too hard, and then running the head very hot for subsequent castings.

This non-water-cooled mold, however, is only good for six or seven hundred castings before it checks sufficiently to be of no use. To make as perfect castings as they obtain, would be the work of a very skilled mechanic, and would cost the manufacturers in this country too much to make the mold for the number of castings which they get out of them.

The Ford Motor Company experimented some years ago on making piston ring pots centrifugally. They built a very compact little rig, driven by a motor, and cast liners for their heads, which they took out with each casting. Their production was tremendous, they having five or six machines in a row, one man pouring off, a man coming behind him and stopping the machine, a third man pulling out the casting with the liner on it, a fourth man putting in another liner, and, by that time, the mold was ready for the pouring-off man to pour some more metal. They never admitted to me what their difficulty was, but, although their metal was a very soft mixture, their castings were slightly chilled on the outside and were subsequently annealed. This chill probably went in deep enough so that the temper carbon portion of the casting was not entirely cut off in making the rings, and the rings undoubtedly wore out very rapidly. This, of course, is my own judgment of why the Ford company abandoned this method.

The Ford company also experimented on making their flywheels centrifugally. Here they used a cast iron mold, setting the mold in the machine. The castings were dumped quick enough so that the heat from the inside annealed the chill on the outside.

The only objection that I can see to their method was that they did not use a water-cooled mold, and used cast iron molds instead of steel molds, for cast iron molds very soon crack up.

The writer does not have the figures of the Ford company as to how many castings they obtained from a mold, but knows from his own experience that they could not have obtained more than five or six hundred. This made the replacing of

the molds excessive, and increased the cost of the method beyond that of making sand molds. I still believe that, had they water-cooled their molds, and used steel instead of cast iron, the arrangement would have worked out satisfactorily.

Discussion—Centrifugal Casting of Iron Piston Rings

By F. W. Stokes, Chesterfield, England

Mr. Rathbone's initial trouble seemed to be one due to the chilling of the material if he used an unlined metal die and the consequent destruction of the required properties by subsequent annealing. As a matter of fact, initially we had a similar trouble here, but we have not found it necessary to line our dies with any refractory material and have been able to adjust matters by care in analysis and regulation of pouring and die temperatures.

Our dies are of cast iron and in many respects we have found these more satisfactory than steel, as our experience was that these were subject to serious distortions. The dies, which I think Mr. Rathbone refers to as the head, are made of a low phosphorus iron, and we are on the average, producing 1,000 castings per die before additional machining is required. For your information, the chief product of our centrifugal shop is a piston ring drum for cutting up into piston rings and these we stock for the trade. When a die has deteriorated on the surface to such an extent that it is unworkable, we can, by taking out a millimeter from the inside bore, use it again for the next size on our list. By this means, the average life of our die is extended to some 4000 to 5000 castings, and in special cases we have reached figures very much in excess of these.

Another point which interested me in Mr. Rathbone's paper was, his reference to chilling on the inside surface or bore of the castings. We have only experienced this difficulty once or twice, and in each case we found that the cause was due to an excess of sulphur in our iron. The iron sulphides being lighter than the remaining constituents of the metal are forced to the inside, or bore of the casting, thus, although the sulphur

FIG. 1—IRON CENTRIFUGALLY CAST SHOWING CELLULAR DISPOSITION OF GRAPHITE, UNETCHED, X 100

may be quite normal, if a thick casting is being produced, the percentage of sulphur on the inside skin of the casting may appreciate in an alarming manner; sufficiently on occasion to cause a sulphur chill. This effect can very readily be seen by taking a sulphur print across a section of a thick casting and by taking analyses from the inside and outside portions of the metal. It is certainly remarkable to me that, apart from this sulphur effect, Mr. Rathbone should have experienced chilling on the inside, unless he has been using very low silicon iron.

I am not sufficiently informed as regards American conditions to appreciate why Mr. Rathbone should think that the method which we are using here, namely, (casting direct from a metal die and avoiding chill by careful choice of mixture) should not also be applicable in your country or why you should have more difficulty in producing satisfactory heads or dies than we have. During the past year we have produced some 100,000 castings by the centrifugal method and on a trial run we were able to produce at the rate of one casting per minute from one machine for a period of half an hour.

I quite agree with Mr. Rathbone's remarks regarding the bad effects of using annealed iron with the carbon in the temper form for internal combustion work. On the other hand, the large plated form of free carbon as produced in a sand casting is a constant source of weakness, and in my opinion, is also the cause of the troubles due to growth. The formation taken by the free carbon in a centrifugal casting which is taken in the grey condition direct from the die without subsequent treatment, is, I think ideal: Fig. 1 is of a photograph showing this distribution herewith Magnified to 100 times, the small colonies of free carbon show distinctly as groups of exceedingly small plates.

Gray Cast Iron From the Point of View of the Electric Furnace

By G. K. Elliott, Cincinnati, Ohio

Although widely discussed, the use of the electric furnace for gray cast iron still is so limited that there is much misunderstanding and ignorance concerning the relations that exist between the elements in cast iron and the operations that are conducted in the acid and the basic electric furnaces. A correct understanding of the chemistry of both the acid and the basic-hearth electric furnaces should lie at the foundation of every decision for or against the adoption of the electric furnace in competition with the cupola. This understanding of course is indispensable in making a choice between the two kinds of electric furnace.

It is the writer's purpose in the present paper first to outline very briefly the main features of the acid and the basic electric furnaces, then to sketch the effects of each upon the principal elements of cast iron in comparison with the effects obtained through the cupola, and finally to touch upon a problem or two of cast iron that have arisen through the introduction of the electric furnace for treating cast iron.

Acid and Basic Linings

The acid electric furnace is lined throughout with materials that are acid in their chemical properties and reactions. Especially is the hearth or bottom made of acid material which always is some form of silica. By a chemist silica would be described as de-hydrated silicic acid. Ganister is the form of silica most widely used for acid hearths. The side-wall from the slag line up and the roof are made of silica brick. Using acid material in the hearth makes possible the employment of highly siliceous or acid slags on the surface of the metal. These are hardly as active as basic slags but they serve the excellent purpose of protecting the metal from the furnace atmosphere and of assisting in a certain amount of refining.

Acid furnaces are simpler to operate than basic ones; also acid refractories are cheaper than basic ones.

The basic electric furnace has its hearth built up of sintered magnesite, chemically a base. Above the slag line it is lined entirely with silica brick in a manner similar to the acid furnace. Therefore the sole difference between the acid and the basic electric furnace is in the material making up the hearth. The magnesite bottom of the basic furnace makes it possible to work the metal under a lime slag which also is basic and accordingly not incompatible with the hearth material. A lime slag would attack quickly an acid bottom just as an acid slag would quickly ruin a basic bottom.

In the preceding paragraphs no attempt has been made to do more than outline in simplest form the two kinds of electric furnace hearths. In the following there will be introduced points of difference in their behavior towards molten cast iron.

Regulation of Carbon

Aside from the iron itself, carbon is the most important element in cast iron, and it is its presence in large quantity in the uncombined or graphitic form that distinguishes cast iron from steel. Its quantity and condition determine the hardness, the strength and many of the other mechanical properties of iron. Therefore it is most important to know exactly what effect the various furnaces we are considering, have upon this all-important element. In the cupola the iron is at all times in intimate contact with carbon in the form of coke and the tendency is very strong for the iron to approach the saturation point in dissolving carbon. Thus the writer has seen charges containing from fifty to one hundred per cent steel going into the cupola with a gross carbon content of from 0.2 to 1.80 per cent (depending upon the percentage of steel in the charge), and coming out at the spout with 2.50 to 3.00 per cent total carbon. The natural tendency of the cupola is to saturate as nearly as possible the iron with carbon. The only regulation of carbon that can be attempted in the cupola is by dilution with steel additions as is often practiced in the manufacture of so-called semi-steel. Even here the influence of the cupola is

toward wiping out the theoretical effects of this dilution. It is a difficult task effectively and accurately to regulate the carbon of iron in a furnace in which the molten iron constantly is in intimate contact with incandescent carbon.

In the electric furnace, acid or basic, carbon regulation is ready and accurate. Carbon reduction is obtained with almost mathematical precision by diluting with steel because the adverse features noted in the cupola are entirely lacking. In fact the mixing of cast iron and steel in the electric furnace produces the truest semi-steel that is known; it lacks the freakish uncertainty of the usual cupola product. Another method for carbon reduction that is made possible by the electric furnace, but one that is practiced very rarely, is to oxidize it out of the iron by means of some form of iron oxide thrown upon the bath in emulation of the common practice of the steelmaker.

By additions of powdered coke of good density, carbon may be built up in the electric furnace. Up to about 3.20 per cent this is accomplished fairly readily, but from there up, although possible and frequently done, the process is fraught with danger of long drawn out heats or failure. When total carbon of 3.50 per cent or higher is desired it is most economical not to rely upon the furnace for an excessive amount of carburization. The subject of carburization is one of the most important connected with the electric furnace metallurgy of cast iron and is in need of further study and wider dissemination of existing reliable information.

Importance of Silicon Control

Next to carbon the most prominent element in cast iron is silicon. It is the chief intermediary through which the foundryman reaches the carbon and bends it to his will. It does much to control the condition of the carbon, determining whether it be combined as carbide or uncombined as graphite. In the cupola a certain amount of silicon always is lost by oxidation, although in a well managed cupola it is capable of very satisfactory regulation by making the original silicon of the charge high enough to take care of the anticipated loss. In the basic electric furnace there generally is a loss of 0.10 to 0.20 per

cent, although not always necessarily a loss, depending upon several factors. In the acid furnace there is no loss and, under favorable conditions, there can be a very material pick-up of silicon reduced from the siliceous slag. In either kind of furnace silicon is increased most easily by additions of ferro-silicon. Raw materials always should be chosen so that it never is necessary to reduce silicon in the electric furnace because the deliberate throwing away of silicon is economically wasteful, although it can be done either by dilution with material low in silicon or by oxidation.

Manganese

Manganese has at least a two-fold importance in cast iron. In the first place it takes care of the sulphur, holding it as manganese sulphide instead of the more harmful iron sulphide. In the second place the manganese not thus engaged forms carbide and thereby has a very perceptible effect upon the hardness and other mechanical properties of iron. In the cupola, manganese suffers a loss generally running from 0.10 to 0.20 per cent. As with silicon this is the result of oxidation. In the acid electric furnace the loss of manganese may reach 0.40 to 0.50 per cent which has to be made up by additions of ferromanganese late in the heat. The basic furnace, on the other hand, is rigidly saving of manganese, the loss being ***nil***, except under an oxidizing slag such as never is used for cast iron. Low-manganese iron can be taken from the basic electric furnace only when the original charge is low in manganese. Another point concerning this element is that electric-furnace cast iron does not seem to require as much manganese as does the cupola product in order to produce a given quality of iron.

Phosphorus

Phosphorus is a more vital element in cast iron than many persons suppose. It has much to do with fluidity and one feels like declaring that it has done nearly as much to popularize gray cast iron as has any other factor, accomplishing this by reducing certain hazards which are apparent whenever low-phosphorus iron is being handled in the foundry. What would the great majority of iron foundries do if deprived of all

medium and high-phosphorus pig irons? In the cupola phosphorus undergoes no change and whatever goes in comes out—sometimes plus a small amount that was in the coke. In the acid electric furnace there is no effect possible upon phosphorus. In the basic furnace theoretically it is possible to reduce phosphorus and it is done commonly in steel practice, but for cast iron it is thoroughly impracticable. It could be eliminated only through oxidizing, basic slags; but before being within reach of the reaction practically all the carbon, silicon and manganese would have to be removed by oxidation. In other words the iron first would have to be reduced to steel, then after dephosphorizing the carbon, silicon and manganese would have to be put back in the iron—the steel remade into gray iron.

Nevertheless the electric furnace has an important relation to phosphorus in cast iron in that, through its infinite power of superheating, it makes possible great fluidity in iron low in phosphorus. There is no doubt that phosphorus subtracts from the physical endurance of castings especially those that are subjected to shock, vibration and other dynamically applied stresses. Because of its weakness as a superheater the cupola is not always able to deliver low-phosphorus irons with the needed fluidity. Considering for the moment the duplexing process, an electric furnace will in considerably less than an hour, superheat to a degree of fluidity that is ample for any purpose, the sluggish melt from a cupola struggling with low-phosphorus iron.

Sulphur

Sulphur usually is viewed with the greatest charity because it is somewhat of a necessary evil in cast iron. In the cupola there always is a very pronounced increase in sulphur extending from 0.02 per cent where the best grade of coke is used to over 0.05 per cent for the poorer grades. As cast iron is remelted over and over its sulphur becomes progressively higher and higher. In the acid electric furnace there is no change wrought in the original sulphur except in the case of high sulphur (about 0.150 per cent) and high manganese when by a kind of flotation the manganese sulphide may rise

to the surface of the bath by reason of the lowered viscosity of the metal at the high temperature.

In the basic furnace there occurs with sulphur one of the most valuable reactions connected with the electric furnace metallurgy of cast iron. Due to the calcareous slag and the deoxidizing conditions brought about by the use of powdered coke on the slag, sulphur is effectively reduced by a series of chemical reactions which may be summarized in the following simple reaction,—

$$MnS + CaO + C = Mn + CaS + CO$$

Often calcium carbide which can be made only at electric furnace temperatures, is formed and aids powerfully in desulphurization. The following shows how desulphurization proceeded in one heat of duplexed iron in which the reduction was pushed to an unusual limit,—

From the cupola	0.156%	Sulphur
10 min. in E. F.	.133	"
20 min. in E. F.	.112	"
30 min. in E. F.	.079	"
40 min. in E. F.	.036	"
50 min. in E. F.	.031	"
64 min. in E. F.	.014	"

One of the problems for which the electric furnace is responsible concerns the true effect of sulphur upon the mechanical properties of gray cast iron. The basic furnace has made easily accessible lower sulphur castings than previously were ever thought possible. As a result there has arisen some question as to the value of extremely low sulphur in gray iron and as to how high sulphur can go without working harm. There is a marked lack of convincing information and a great mass of contradictory evidence about the influence on iron of those non-metallic inclusions, the sulphides. The writer desires to make no brief for excessively low sulphur nor does he deny that excellent castings are made with irons fairly high in sulphur, but his strongest conviction is that castings low in sulphur are worthy of the greater confidence because one can rest assured that they were made either from good pig iron and scrap, expertly melted and cast under favorable conditions, or else from iron that has passed through a drastic

deoxidation and refining—as in the basic electric furnace—that has reduced not only sulphur but also oxides and perhaps other impurities more harmful than sulphur itself. The presence of sulphur in quantity need not unconditionally condemn an iron but certainly its absence is a strong recommendation. Low sulphur in a casting cannot be considered otherwise than a stamp of quality.

Tests Needed to Show Effect of Phosphorus and Sulphur

In considering the sulphur problem we are brought face to face with another problem of cast iron which concerns methods of mechanical testing. To the writer it seems that the present standard tests for gray iron are sadly lacking in scope and variety when put to the task of detecting the more latent virtues of different varieties of iron. The most of our tests of iron are transverse with tensile tests made to a lesser extent; hardness tests also are made in a few plants, which about completes the list.

Transverse and tensile tests both are decidedly static in nature, and, because of the peculiar structure of cast iron, are admirably fitted to give the most flattering estimates of its mechanical properties. The writer hopes to see the introduction of tests of a more dynamic nature because he believes they may reveal shades of difference in cast irons to which the customary tests are not sensitive. The available literature for example contains so little concerning the resistance of cast iron to impact that we urge a freer distribution of existing data, if there be any, and a more systematic gathering of fresh data by testing many varieties of cast iron. In urging this we are in full knowledge that cast iron is at its worst under these conditions but it is felt that more rigorous tests may disclose differences to which the usual tests are entirely blind. Perhaps they may make manifest some of the elusive effects of varying proportions of phosphorus and sulphur. Dynamic tests may help clear up the sulphur problem. In this connection the writer is glad to record that a committee on impact testing has been organized very recently by the American Society for Testing Materials and that one member has been chosen especially to represent cast iron upon this committee.

Discussion—Gray Cast Iron From the Point of View of the Electric Furnace

V. D. Miller.—I would like to ask Mr. Elliott, although he has not touched on the point in this paper, if it is possible to make a higher grade cast iron at less cost in the electric furnace, say by the acid process, on account of the possibility of charging scrap, due to a lower first cost in raw material. In my opinion, due to the lower cost of raw material, you can produce a superior iron in physical qualities at a considerable less cost. As I understand it, they use in cupola practice a fairly high-silicon pig, and that fluctuates in the market anywhere from $32.00 to $37.00 a ton. Now by using scrap and also by remelting the leave-overage from the castings which are not built up with sulphur as in the case of the cupola, it seems to me that a superior grade of iron can be made at much less cost.

G. K. Elliott.—There is no doubt that you can make a high-grade iron especially in the basic electric furnace, melting low-grade scrap, but before we can really discuss this intelligently, we would have to fix some standard of grade. I should imagine there are some grades of iron so high that they would be entirely out of reach in the cupola, and in that case any comparison of cost would be entirely unnecessary, but I imagine we have a grade which is within the scope of the cupola and I am not willing to go on record as saying that we can always make it cheaper in the electric furnace, even using scrap. Those who heard me discuss this subject will probably recall that I never overlook an opportunity to impress upon the audience that I am a very staunch friend of the cupola; I think it is the most wonderful melting furnace we have; there is nothing to touch it in cheapness, and when you back the electric furnace up against the cupola on the question of cost, it is up against the stiffest opposition there is in the world. There is a man

in Alaska who can make it cheaper in the electric furnace, because his iron costs him $48 and $50 a ton, but it is a question what the current is going to cost you in the electric furnace.

V. D. Miller.—My quarrel with this whole thing—you and I have scrapped over this once or twice before—my quarrel with the whole gray iron industry is this, that there is no classification of gray iron, you might say, a man sells gray iron and he sells gray iron, whether it is 0.07 or 1.1 or 1.2, it is gray iron. It seems to me it is up to the gray-iron men to classify or stratify, whichever you want to say, their gray iron into certain grades and stiffen up on this specification so that a 0.11 sulphur iron will not be classed as gray iron of the same character as 0.07; yet a man will order gray iron and if he gets anything within reason, he will take it and thinks it is all right. Now the steel industry is very different in that way: they have very drastic specifications, and it seems to me the entire gray iron industry would benefit by stiffening up and making their lines of demarcation very distinct, and in spite of what Mr. Elliott says, I maintain that a high-grade gray iron can be made very economically in the furnace if you insist on a low sulphur.

G. K. Elliott.—If you insist on a low sulphur; I doubt whether most of the foundry men represented here are making castings on a strictly competitive basis, maybe you and the jobbing foundries are, and the man who buys your castings probably thinks all cast iron is the same and doesn't care whether it is 0.07 or 0.7 sulphur. If, however, you have an educated customer who asks to have a certain high grade of iron to suit his purpose, you have a chance with the electric furnace, but you cannot use it promiscuously all over this broad land of ours because so many castings are sold on such a keen competitive basis that the electric furnace cannot compete with the cupola.

V. D. Miller.—Would not that be corrected by stiffening up on your specifications and grading your iron?

G. K. Elliott.—That is up to the engineering profession; educational work the foundrymen cannot do. You have to get back to the consumer of the casting and get him to ask for something better. The average foundryman cannot force his

customer to buy better grades of castings when he is getting satisfaction out of a lower grade. You have to educate the consumer up to the fact that all cast iron is not the same, that there are many different grades, and as that education works itself out among the consumers, the demand for high-grade castings will increase and is increasing now, and as that happens, the electric furnace will come more and more to its own.

J. D. Stoddard.—There has been a great deal said about classifying castings in accordance with the sulphur content and stiffening up specifications in regard to the amount of sulphur contained. I believe it is quite true that some castings contain higher percentages of sulphur comparatively and are of very much better quality for the purposes intended, as far as use is concerned, than other castings containing a very low sulphur. I have in mind a case that came to my attention recently where a foundryman in Detroit was making hoop bolts for an automobile company, and the castings were of such high carbon content that when they came to tap out their threads in the center, they could not possibly get a clean thread, it would tear and drag, and in order to overcome that he went and added iron sulphide to the ladles, increased his sulphur up to about 0.1 per cent and got a perfect machine casting, and the castings were plenty strong enough and were improved by the addition of sulphur. I have known of many cases where castings for particular uses have been materially improved in quality by an increase in sulphur, sometimes two or three times the amount that the casting normally contains.

Col. Mangot.—I would like to ask Mr. Elliott about the possibility of utilizing turnings in the furnace, if there is a possibility that turnings can be used to advantage in the steel furnace?

G. K. Elliott.—You can take a pencil and paper and look up the market price of cast-iron pipe turnings and figure out for yourself in a short while on paper, whether it will pay. If you try to do it in an electric furnace, you are apt to lose a fortune handling cast-iron turnings in an electric furnace, it is not the snap it sounds like. It is difficult to melt them, there is so much air surrounding all the little particles and it takes

the heat so long to pentrate the mass that it is a very expensive thing to do. I have done it a few times, but it takes so long and requires so much hard work, it needs a constant rabbling of the heat, probably some of these furnaces that gyrate back and forth or rotate, will be better, but we have none of them of the capacity needed in the iron foundry.

V. D. Miller.—Would not that condition be helped somewhat by getting a molten bath first for some of your heavier scrap and then dump the turnings into this molten pool, allowing the molten metal to fill up the air interstices and make this approach more nearly an ingot? Then you would have a solid metal filling up your air interstices, which would make up the amount of metal.

G. K. Elliott.—That has been tried but it does not work so well, there is such a thing as getting too solid a charge in a furnace. It sounds strange to talk about a flame in an electric furnace, but there is something like a flame, you want your charge to open somewhat so that the arc can penetrate it. I do not think anybody has had very much success except with pencil and paper, in melting all kinds of things in the arc electric furnace.

F. J. Ryan.—I do not think that the question of using turnings in a charge is one that is very serious. If the correct proportion is used, I know of a great many electric furnace installations, especially during the war which utilized cast-iron turnings. If the correct proportion of scrap is used, as high as 35 or 40 per cent, you can get very good results. You can only get about a ton of turnings in a three-ton furnace. It is not so bad with cast iron as with steel—if you try that with steel, you will pull the inside of the furnace out with it. If you put a good heavy melt of heavy scrap in the center and work the turnings into it, you won't have a great deal of difficulty with it.

C. E. Sims.—I have melted turnings, both steel and iron, in the electric furnace very successfully, and as Mr. Ryan has said, the electrode does tend to burn down through there, it is not so much the material in the way of the electrode as the arc starts arcing on the material and burns a hole through it

right down to the bottom and then it is no longer in contact with the material, but if you take a piece of electrode and put it in after it burns a little hole and let it arc on the electrode, on this piece of graphite, it will then melt by radiation from the arc rather than by direct contact, until it gets a pool. After a pool of liquid metal is formed, it melts very readily. I have taken a charge of all steel turnings which do weld together fearfully at first, but they all melt. Another way I have done in mixing the cast iron is to put a large carbon on the bottom of the furnace between the electrodes, have the electrodes melt down through, and then this large carbon carries the current and the charge melts from below. That was done quite successfully.

Electric Furnace Iron From the Managers Standpoint.—A Review of Conditions as They Exist

By L. J. Barton, New Orleans

During the past few years electric furnace iron has entered practically all foundry discussions. Some oppose this idea, while others strongly advocate. The main purpose of this paper is to show how one company has figured the question.

Under present conditions of keen competition the question of making iron castings resolves itself into a strict price proposition. The buyer undertakes to fill his requirements at the lowest possible figure which is no more than natural. In the vast majority of cases he requires an iron which has a nice smooth appearance, and is readily machinable. The very important questions of strength or quality of the metal itself are neglected. There are, however, cases where quality is of prime importance, and in such instances the purchaser is more than willing to pay a higher price. These instances are rare and in very many the castings themselves are not bought on the open market, but are made in the manufacturers own shop. Several notable instances of this are in high pressure valves and fittings, piston rings, resistance grids, and such work. Therefore the first question arising with electric iron is the cost of manufacture. Can it compete with the cupola?

This is a question which can be answered both yes and no. In the eastern and central sections of the country there is lack of cheap power, an abundance of cheap pig iron, and plenty of cheap coke. These points are overwhelmingly in favor of the cupola. As you move towards the Pacific coast you enter an area of cheap hydroelectric power, with high pig iron and coke due to high freight rates. These points favor the electric furnace.

The question therefore proves to be an economic one, which must be investigated from the angle of various localities, are several analyses of costs of gray iron as made in the electric furnace. On all of them the costs of raw material, etc., are as here shown:

Analyses of Cost

Power

Energy Charge Kilowatt Hours			Demand Charge Kilowatt Hours		
1st. 500	@ 5	cents	1st. 5	@	$15.00
Next 1000	@ 3	cents	Next 15	@	2.50
Next 3500	@ 2½	cents	Next 30	@	2.25
Next 45000	@ 1	cents	Next 150	@	2.00
Over 50000	@ ¾	cents	Over 200	@	1.50

Less 50 per cent on demand charge for avoiding use of current during peak hours between 5 and 7 p. m.

Fixed charges depreciation, interest, insurance $4800 per year.

Supervision $5000 per year.

Labor	Melters	@	75	cents per hour.
	Helpers	@	50	cents per hour.
Electrodes		@	8	cents per pound.
Ferro-alloys		@	5	cents per pound.

Brick, slag material, magnesite, etc., at market prices.

3 Ton 'Lectromelt Furnace Pouring 4-5 Ton Heats

Operation	Acid		Basic
16 hour	24 tons		20 tons
Labor	$ .835		$1.00
Power 550 KWH	6.100	600 KWH	6.87
Electrodes 24 pounds	1.92	30 pounds	2.40
Brick	.500		1.00
Repairs-patching material	.100		.25
Slag making material	....		.50
Alloys	.500		.25
Miscellaneous-water, tools	.200		.25
Fixed charges & supervision	1.370		1.96
Conversion	$11.525		$14.480
24 hour	36 tons		28 tons
Labor	$ .835		$ 1.07
Power 525 KWH	5.250	560 KWH	5.80
Electrodes 20 pounds	1.600	24 pounds	1.92
Brick	.400		.75
Repairs	.100		.25
Slag material	....		.50
Miscellaneous	.200		.25
Alloys	.500		.25
Fixed charges & supervision	.910		1.16
Conversion	$9.795		$11.955

We now have a series of figures on which to base our calculations. There are yet two available methods of making our iron—from the cupola direct, and duplexing. In the locality of the country from which the above costs are figured it costs close to $5.00 per ton to convert the iron to a molten condition in the cupola. Duplexing over a 6 hour period will cost $4.96 per ton, with a tonnage handled of approximately 30 tons.

Our present supply of scrap metal is fair. Considerable amounts of borings and turnings are at hand at a price of from $5.00 to $7.00 per ton. Cast iron scrap brings a price of $18.00, while low grades of melting steel can be had in quantity at $12.00. Pig iron costs close to $30.00 at the cupola.

Our general mixture in the cupola for castings which must be machined is 50 per cent pig, and 50 per cent scrap cast. For general work, where there is no machining, scrap cast alone is used, often with varying percentages of steel. If duplexing was used this cheaper scrap mixture could be used for machinable work. We therefore can now enumerate the costs of molten metal using standard losses.

Cupola	$30.20 per ton	
Duplexed	$28.86 per ton	
Basic Electric	16 hour operation	$33.02
	24 hour operation	30.49
Acid Electric	16 hour operation	$30.07
	24 hour operation	28.34

These figures are all for machinable castings, using 100 per cent scrap cast as the electric furnace charge. While it must be also necessary, when using the electric process, to figure in night pouring gangs, it is also true that they can shake out castings, temper the sand for the next days molding, etc., which does not add any extra labor cost to the final figures.

The above comparative costs show that the electric furnace under our conditions of operation will compete with the cupola on straight tonnage and price. When borings are used for the charge there is a further saving effected in

favor of the electric furnace, and as we also operate a large machine shop this figure assumes importance.

Quality and Versatility of the Electric Process

So much has been written of the quality of electric furnace iron that little needs to be said. The point of importance is that by using the superheated metal the percentage of lost castings drops, which is a further point in favor of the electric furnace.

Another important phase is the ability of the electric furnace to work on both iron and steel, and by means of this double tonnage continuous operation, with its low costs, becomes possible. The foundry then has two lines open, and if the demand for steel becomes too great the cupola can always be called on for a heat of iron, or duplexing can be resorted to.

For the cheaper grades of iron, where no machining is done, steel borings can be melted in the electric furnace, and synthetic iron made at a cost of approximately $20.00 per ton.

Comparison of Acid and Basic Electric Process

Providing you have decided to adopt electric furnace iron the next question arising is which process you will use, acid or basic. As you intend to make steel also this question must be handled with a view to both products. The advantages and disadvantages of both are here enumerated:

Acid Process	Basic Process
1. Lower conversion costs.	1. Can use cheaper melting stock.
2. Larger tonnage over a given period.	2. Uses less alloys.
3. Superheats.	3. Superheats, deoxidies, and desulphurizes.
4. Iron free from non-metallic inclusions.	4. Clean iron, elimination of "oxide cracking."
5. Hotter metal.	5. Regular analyses.
6. Silicon control difficult.	6. Ability to make alloy mixtures.

The governing point here is the difference between conversion costs, and the price of suitable melting stock. If acid scrap is so high that the difference counteracts the lower conversion cost basic operation must be used. In the

vicinity of New Orleans this is the case, acid scrap costing from $20 to $25, and high phosphorus basic steel scrap $10 to $15, making basic operation the cheaper in the end. (This factor is governed by our steel operations which is our first consideration.)

In such shops where the normal tonnage is sufficient to take care of the electric furnace output without making steel it will generally be found profitable to use acid operation, the greater tonnage available over a certain period, and the lower conversion costs being the deciding factors in this instance.

While the foregoing is illustrative of the conditions as found by the writer in one locality it may be that conditions in another are adverse to the successful operation of an electric furnace on iron casting work. However, if you are assured of a steady tonnage, sufficient to keep in continuous operation an electric furnace of from 2 to 4 tons capacity I believe it would be to your advantage to look thoroughly into the situation, for what may appear on the surface may not follow when all points are considered.

Discussion—Electric Furnace Iron

G. K. Elliott.—Mr. Barton mentions here the advantages of working both steel and iron in the electric furnace, and I just want to second what he says, that this is a great advantage. There was a time during the war when the deliveries on malleable iron were so atrocious that we made all our malleable requirements for, I suppose five years, in the electric furnace, so many days we ran steel malleable and duplex gray iron all in the same furnace. It might also be added that there is another side to this picture, that sometimes you have some gray iron in your furnace when a steel heat goes in, and the result is that it is pretty hard to convert that iron into steel, and sometimes the

problem is vice versa, sometimes steel hangs over in large quantities and you have the job of recarbonizing gray iron, but as a general thing it works out pretty nicely.

F. J. Ryan.—I think that in considering a paper such as the last one, that sometimes we place a little too much importance upon the relative figures given for some definite locality, and I think the question with the electric furnace iron is just the same as it was with steel; it is a little outside of the question of the direct cost in comparison with the product now being produced in the cupola. I think also that the iron phase of the electric furnace is going through the same situation that the steel furnace went through. Of course, I speak from the standpoint of the furnaceman and have the advantage of going through the period of the introduction of the electric furnace in the steel industry. I know that when we first tried to introduce the electric furnace in the steel industry, everything was competition. What is the cost of production; what would be the cost in comparison with what I am now producing? In as much as we might optimistically say that the cost would meet the competition of the old-time converter and the rest of it, we all at heart know that in relation to the same productive conditions, the electric furnace is more costly. We still have our open-hearth and other methods, but the electric furnace, through the propaganda we have worked out, of the superior product, brought the attention of the consumer to a superior product and made other lines step up and made a better product, and as a result it brought the whole industry along together. It seems to me that right now, from the standpoint of the manufacturer of electric furnaces and the knowledge of the cost of production, while I can pick out two or three cases where the cost would be lower than the average cupola, taking the general average, it is not lower and there is no use trying to beguile ourselves into that belief. There may be such a condition once in a while, but there is a distinct chance of improvement of the cast iron.

Manufacture of Synthetic Foundry Iron in the Electric Furnace[1]

By C. E. Sims, C. E. Williams, and B. M. Larsen
Seattle, Washington

The manufacture of synthetic cast iron is an industry that was created and nourished by war-time conditions, and when the stress of war needs ended, interest in it practically died and is now only slowly reviving. However, with increasing knowledge of proper methods of production and a growing demand for high quality castings, it is expected that this revival will continue and put the industry on a successful peace-time basis.

The manufacture of synthetic foundry iron would create an outlet for a large quantity of scrap iron and steel of such a nature that it is now difficult to dispose of or which is being put to uneconomical uses. It should be a boon to the founder who is at a distance from an iron-producing center and must pay an excessive price for pig iron and often experiences difficulty in obtaining the quantity or quality of iron that he needs.

Conditions in the far western States of this country where pig iron and good foundry coke are expensive and iron and steel scrap and electric power comparatively cheap, are particularly well adapted to this industry. These conditions make cupola melting less desirable and favor the production of synthetic foundry iron, which is essentially an electric furnace operation. The same furnace equipment can be used either for the electric melting of foundry iron or for the production of synthetic cast iron, so that instead of requiring a specialized apparatus, the production of synthetic foundry iron employs an instrument of general usefulness. Since the carbon content of the product can be varied between wide limits and silicon and other alloys

1. Published by permission of the director, United States bureau of mines.

can be added easily, gray or white cast iron, or other similar products may be made with equal facility. One particular field in which synthetic cast iron has an advantage is in the production of low phosphorus castings. For certain kinds of castings, such as ingot molds which must withstand abrupt temperature changes, low phosphorus cast iron is necessary, and low phosphorus pig iron is not always available. Phosphorus cannot be removed from pig iron, but synthetic cast iron made from steel scrap would, of course, be low in phosphorus. Furthermore, as there is a rapid growth in the trend toward definite specifications of iron to be used for special purposes, the fact that synthetic foundry iron of any desired composition can be made, makes it particularly valuable.

Although a carbon content of three per cent is sufficient for many grades of castings, the great majority will require 3.25 to 3.75 per cent and very few contain less than three per cent. If the synthetic cast iron is to be pigged for future cupola use, it should contain from 3.75 to 4 per cent carbon.

Although the most important factor in producing synthetic cast iron is obviously that of introducing the requisite amount of carbon, this is the very point where most of the work done has been weak. Turnbull[1] in his early work was rarely able to get carbon over three per cent but in his later improved operations occasionally reached 3.5 per cent. He stated that it was extremely difficult to raise the carbon above three per cent in a roofed furnace without great damage to the roof and that all high carbons were obtained in open-top furnaces. Likewise, Keller[2] mentions three per cent carbon and gives one analysis of a white iron containing 3.55 per cent carbon. In discussing Keller's article, Brooke said it was easy to obtain a carbon content of 2.75 per cent, but was difficult to get one of 3.75 per cent, especially if a roof was used. Richards in the same discussion,

1. Turnbull, Robert, Electric Pig Iron in War-Time: *Transactions American Electrochemical society.*, vol. 32, 1917, pp. 119-127; also Electric Pig Iron After the War: *Transactions Electrochemical society, vol.* 34, 1918, pp. 143-148.

2. Keller, Charles A., Synthetic Electric Furnace Cast Iron: *Transactions American Electrochemical society*, vol. 37, 1920, pp. 189-206.

reports that the use of the roof was abandoned in order to obtain the high carbon content of three per cent. Cawthon[1] found that over 2.75 per cent carbon could be introduced by cleaning the bath free from slag and agitating with a green pole.

The factors affecting the rate of carburization were studied by the authors and reported in a paper presented before the Baltimore meeting of the American Electrochemical Society in April, 1922.[2] This paper outlined the best conditions for rapid carburization and showed that from 3.5 to 4 per cent carbon can be introduced without difficulty. By holding the molten metal in the furnace in contact with the carburizer, a product containing as much as 4.8 per cent was obtained. The experiments described in the paper referred to were conducted in a 50-pound open-top pit furnace and in a 300-pound roofed direct-arc tilting furnace. The roof furnace was found to be preferable and even when producing a carbon content of 4.8 per cent no unusual damage was done to the roof, although it must be remembered that the furnace was small and the pressure on the refractory in the roof not as great as it would be in a large furnace.

It was found in these tests that the following factors contributed toward rapid and complete carburization:

1. Use of a carburizer of as low ash content and as high density as possible.
2. Absence of siliceous slag.
3. The addition of lime to flux the ash introduced when high-ash coke is used.
4. High temperature and direct arc.
5. Early removal of sulphur by use of a lime slag.

In order to determine whether the results obtained in those small-scale tests would apply with equal weight to commercial operation, several charges were run in a basic-lined Heroult type furnace used for melting steel at

1. Cawthon, James L., Synthetic Cast Iron: *Transactions American Electrochemical society*, 1922.
2. Williams, Clyde E., and Sims, C. E., A Study of Carburization in the Manufacture of Synthetic Cast Iron: *Transactions American Electrochemical society*, 1922

the Lamb Machine Co. in Hoquiam, Washington. The furnace was rated at 3000 pounds and took an input of about 400 kilowatt. Inasmuch as this appeared to be underpowered for carburization work, only 2000-pound charges were made. The steel scrap used was a mixture of blacksmith shop scrap, corroded boiler flues, cast-steel sprues and gates, boiler punchings, etc. Runs were made using high-ash coke containing about 30 per cent ash and retort coke practically free from ash. in order to determine the effect of ash content of the carburizer. Ferrosilicon and ferromanganese were added in the quantities required.

The progress of carbon solution was watched by inspecting fractures of slowly-cooled samples taken at intervals from the furnace. This method has proved very satisfactory when used by an experienced operator. After the desired amount of carbon, between 3.5 and 3.8 per cent, had been introduced, the metal was poured into ladles and thence into molds for a variety of castings, such as pulley wheels, bushings, grate bars, etc., satisfactory castings being obtained in every instance.

The results proved that the conclusions arrived at as a result of the small-scale tests in the laboratory applied equally to large-scale operations. The presence of a siliceous slag deterred the rate of carburization, a large amount of slag practically preventing any introduction of carbon; carburization took place rapidly if the surface of the metal was kept clean; high-ash coke was less effective than coke of lower ash content; and finally the carbon content of the product was adjusted to the desired point by holding the metal in the furnace and observing the nature of the fracture of ladled samples.

Keller[1] used fine turnings with coke in approximately the same state of division and contended that with such an intimate mixture, carburization started far below the melting point and was largely completed before the charge had melted. Our experiments have shown that this is not true but that very little carbon is introduced until

1. Keller, Charles A., Synthetic Electric Furnace Cast Iron: *Transactions, American Electrochemical society*, vol. 37, 1920, pp. 189-206.

the scrap is molten. The heaviest steel scrap that could be put into the furnace carburized as rapidly as fine turnings and borings. Molten iron was found to absorb carbon up to 2.5 per cent with great rapidly when allowed free contact. Strips of Armco iron whose melting point is near 1500 degrees Cent. were placed in a tall crucible with ground retort carbon at the bottom and heated in vacuo. No action was noticed until a temperature of about 1250 degrees Cent. was reached, when melting started and was completed in a fraction of a minute. It seemed that the small portion of the iron in actual contact with the heated carbon, after reaching the plastic state became sufficiently carburized for the surface to melt. This molten portion rapidly carburized to 2.5 per cent carbon, and acted as a flux to melt more iron which, in turn, was carburized. Thus a progressive fluxing, melting and carburizion is set up which quickly changes the low cabon solid iron to high carbon molten iron much as salt melts ice below the freezing point of water.

Attempts have been made by numerous investigators to produce synthetic cast iron in the cupola. Robert E. Masters[1] reports that he melted steel in the cupola over 50 years ago and Moldenke[2] has melted thick steel scrap using large fuel ratios. Moldenke[3] also described a German process for making synthetic foundry iron in which steel borings are briquetted and melted in a cupola with ferrosilicon and a large excess of coke. Valuable information regarding the extent of carburization obtainable in the cupola was obtained by the research department of the Rombacher Hütte in Coblence.[4] The cupola was first charged with coke to 7¾ inches above the typeres, then more coke with limestone was added, followed by additions of low-carbon steel scrap, limestone and ferrosilicon. The carbon content of the products obtained using light scrap was from 2.70 to 2.95 per cent, and that of products from

1. Masters, Robert E., Melted Steel in the Cupola: *The Foundry*, vol. L, p. 1008.
2. Moldenke, Richard, Principles of Iron Founding: McGraw-Hill Co., 1917.
3. Williams, C. E., and Sims, C. E., discussion of paper "A Study of Carburization in the Manufacture of Synthetic Cast Iron": *Transactions American Electrochemical society*, 1922; also in *Iron Age*, vol. 7, May 4, 1922, p. 1204.
4. Brown, J., Production of Synthetic Foundry Iron and Its Properties: *Stahl und Eisen*, June 30, 1921, pp. 881-888. Also, *Iron Age*, Nov. 3, 1921, pp. 1137-1138.

heavy scrap was from 2.75 to 3.35 per cent. Much slag was formed which attacked the lining badly. Later, molten steel was poured through a column of hot coke in a cupola. The metal obtained by this treatment contained usually from 2.6 to 2.8 per cent carbon. When charcoal was used instead of coke, in most cases the metal produced contained more carbon than this, although the analyses reported varied from 1.90 to 3.56 per cent.

Experiments conducted by the authors using a small cupola proved that steel scrap is difficulty melted with high-ash coke (20 per cent), and that using retort carbon the operations are smooth but that the carbon content of the metal is not high, usually about 2.5 per cent.

As a result of the above observations, it seems that the production of synthetic foundry iron in the cupola is impracticable because of (1) the inability to obtain, consistently, a metal of high-carbon content, (2) the excessive slagging and its consequent troubles, (3) the large proportion of coke required and the consequent introduction of a relatively large amount of sulphur, and (4) the large loss of silicon by oxidation.

From the above discussion, it is seen that both electric furnace and cupola melting tests have shown that 2.5 per cent carbon is readily introduced into iron by melting steel scrap in contact with carbon, that this amount of carbon is absorbed shortly after the steel is melted, and that a relatively longer time is required for the introduction of more carbon. In the electric furnace carbon contents of from 3.5 to 4.0 per cent can be easily obtained by adhering to certain requirements which will be outlined in the following discussion.

Best Operating Conditions

Raw Materials

Practically any ferrous scrap can be used, low or high carbon steel, wrought iron, malleable, white, or gray cast iron scrap being equally desired. Scrap from manganese steel, or high silicon irons, which is often not in demand by the ordinary market, is wanted for synthetic iron to bring

up the manganese or silicon content of the iron. The sulphur and phosphorus content need not be limited since the scrap containing these impurities can be mixed with other scrap to reduce their content and the sulphur is largely removed if a lime slag is used. From the metallurgical standpoint the scrap may be in the form of fine turnings and borings, or heavy sections, the state of division having no effect upon the operations.

Carburizer

The purest and densest forms of carbon are the best carburizers. As the ash content of the carbon increases, more of it must be used and the rate of carburization will be slower. Artificial graphite electrode or resistor carbon, petroleum coke, gas-retort carbon, and pitch coke, are the best carburizing materials. Wood charcoal ranks high because of its purity but is not as effective as the ones mentioned above because its apparent specific gravity is so low that it floats on the bath giving poor contact. Coke and and anthracite coal of low-ash content come next in preference, and the high-ash cokes last. Carburizers of high ash content should be used with a lime slag, and the latter removed once or twice during the carburization period. Silicon carbide is an excellent carburizer but must be used with one of the forms of carbon above mentioned and only in sufficient quantity to introduce the required silicon in the metal.

Addition Agents

Ferrosilicon or high silicon iron are best for introducing silicon, although silicon carbide in the form of "firesand" has proved both cheap and effective and is also valuable as a carburizer. Silicon may be introduced by the reduction of a siliceous slag but difficulty is experienced in regulating the reduction to give the required silicon content. Another objection to the introduction of silicon by this means is that a siliceous slag retards carburization. Therefore considering the extra power required to reduce the silicon and the excessive time needed for carburization

using a siliceous slag, the introduction of silicon by this means is considered undesirable.

Any alloy of iron and manganese is satisfactory for the introduction of manganese, the choice depending upon the cost.

If desulphurization is required, either lime or limestone mixed with fluorspar should be used. The use of silica in the slag must be avoided to obtain rapid introduction of carbon.

Type of Furnace

The furnace operations in the manufacture of synthetic foundry iron are similar to those in the ordinary melting and refining processes for iron and steel, hence the type of electric furnace used for the two processes would be essentially the same. For rapid carburization, hot metal and good contact between the carbon and the iron are necessary. The direct arc furnaces used in steel melting satisfy these conditions in an excellent manner. In them, the heat is applied directly to the charge; the metal just under the electrode is superheated, and its avidity for carbon increased thereby, and the action of the arcs on the metal and the magnetic flux of the current cause a stirring and mixing action which affords exceptionally good contact between metal and carburizer. The indirect-arc furnace, if rocked or rotated, would give excellent mixing, but the stirring action of the arc and current would be less intense.

Continuous melting in the open-top pit furnace has been advocated. In this type of melting, however, it is impossible to raise the temperature above the melting point of the charge, while in the batch run superheating can be carried on to any desired temperature. Therefore, as there is practically no carburization or desulphurization before actual melting, and as both these actions take place much faster and more thoroughly at an elevated temperature, the advantages of the batch melting are evident. Especially where the metal is to be cast direct from the furnace is it necessary that the operation be flexible and

the composition easily and accurately controlled. The use of a roof has been shown to be practical and it is advantageous in facilitating the control of the furnace temperature and atmosphere. Although a tilting furnace is not necessary, it is a great help in the charging, pouring, and slagging operations.

The proper lining is one of the most important features. From the numerous tests we have run, it appears conclusive that a basic or carbon lining is necessary. It is extremely hard to get a three per cent carbon iron when using an acid-lined furnace or an acid slag. Many of the failures of other investigators to make iron of high carbon content can be laid to a slag high in silica. A basic lining and a basic slag must be used if desulphurization is done. The hearth may be made of dead-burned or sintered magnesite, a mixture of magnesite and alumina, dolomite, or carbon, rammed in with a bond. It should be broad and shallow to give as large a surface of metal as possible. The walls should be magnesia brick to a short distance above the slag line.

The furnace, therefore, need not be a specialized type, but of standard design that can be used interchangeably for iron or steel melting. It should, however, be constructed for easy charging of voluminous material and should have tight-fitting doors and electrode rings.

Method of Operation

The methods of operation that have been found to give the best results are given below. Naturally continuous operation is most economical. About seven parts of carburizer are used per one hundred parts of steel scrap. In charging, half of the carburizer is placed in a layer on the hearth, so as to come under each electrode and form a continuous train. The steel scrap is then charged and the rest of the carburizer placed on top of this. If desulphurization is to be accomplished, the lime-fluorspar mixture may be added at this point. The doors are then closed and melting is started. A dual voltage control is desirable using 100-120 volts during the melting stage and 70-80

volts for final carburizing and refining. The electrodes will quickly melt their way through the charge to the carbon train at the bottom which will then carry the current. This is desirable; for the carburizer will quickly reach incandescent heat and will itself aid in melting and carburizing the steel. The melting will thus be from bottom upward and the carbon will always be in contact with the molten metal. The arc will be buried in the unmelted part of the charge which will absorb the reflected heat and at the same time protect the roof. After the charge is all molten, enough carburizer should be kept on the surface to maintain a partially smothered arc. This will insure smooth operation and will be easier on the roof. Too deep a layer of carburizer should be avoided as it will cause the current to short-circuit and pass above the metal with consequent loss of efficiency. Any slag that accumulates should be skimmed off unless a desulphurizing slag is being used. If a hight-ash coke is used, better results will be had by maintaining a strongly basic slag to flux the siliceous ash from the coke and thereby speed up carburization. If a low-ash coke is used and desulphurization is not required, it is far better to use no slag at all and to keep the surface of the melt free from everything except the carburizer.

As soon as the metal is melted and at intervals of about fifteen minutes thereafter a small sample is ladled from the bath, poured into a mold, and allowed to cool slowly to a red heat. It is then quenched and broken for examination of the fracture. If the material charged was corroded or oxidized, the first sample is apt to be gassy, a condition that is quickly overcome by the intense reducing atmosphere of the furnace. When a sample shows thorough deoxidation, the ferrosilicon and ferromanganese are added in the required amount. The advantages of adding the ferrosilicon at this point are two-fold; first, loss by oxidation will be avoided; and, second, after it is added, the spoon samples will show the normal fracture and the carbon can be closely estimated from the amount of

graphitization shown. The time required for carburization will vary according to the amount of carbon desired, but will not be over half the time required for melting. During the final carburization, the metal should be held at a temperature of at least 1400 degrees Cent. and cast at 50 to 100 degrees less than this.

Costs

In discussing the cost of manufacturing synthetic foundry iron many variable factors must be considered. Pig iron may be produced as a primary product of a plant, or castings may be made directly and marketed as finished articles. If pig iron is made, it must be produced at a cost lower than the market value of pig of similar quality in the same locality. Obviously, this phase of manufacture would have limited application. The production of castings, however, has more promising possibilities. This operation may be looked upon from two different standpoints; first, the foundry making a variety of castings could use steel scrap in place of more expensive pig iron, the manufacture of synthetic foundry iron being incidental to the main business of operating a foundry; second, an organization established for the purpose of making synthetic pig iron could make a product such as cast iron pipe that could be produced on a large scale and yet would sell at a higher unit cost than would pig iron, the production of the synthetic foundry iron being the main operation and the casting department only incidental.

The saving that can be effected by direct casting over pigging, for subsequent melting, includes the following: (1) cost of handling of the pig; (2) cost of melting in the cupola which has been variously estimated as between $5.00 and $10.00 per ton, and, (3) the extra time, power, and materials required for producing pig iron which must contain more C, Si and Mn than iron castings; the cost of these will amount to perhaps one or two dollars per ton.

The cost and nature of the scrap available will vary greatly. There will be competition for the good grades

of heavy scrap by open-hearth steel plants and foundries, although some heavy scrap is of such nature as to make it unfit for use in the open-hearth furnace, and yet may be valuable for synthetic cast iron. Light scrap, turnings, and borings will be in demand for use in blast furnaces, if they are in close proximity to the source of supply. Inasmuch as the cost of scrap is dependent upon the demand for it, it would be expected that a new industry using a large tonnage of scrap would cause the cost to increase in proportion to the new demand.

There are hardly two localities in the United States where power rates are exactly alike, but the tendency in growing communities is for lower rates for large steady users of power. Exceptionally low rates for off-peak and seasonal power are now made by some companies.

No estimates of the cost of production will be given here because of the many variable factors involved and the impossibility of choosing one condition that will apply throughout the various parts of the country. However, the quantities of materials required are listed in Table I, so that calculations may be made to suit any conditions that may be under consideration.

Table I

Costs

Materials required to produce one ton of synthetic cast iron containing C-3.50-3.75 per cent, Si-2.0 per cent, Mn-1.0 per cent.

Material	Quantity
Steel scrap, turnings, borings, and misc	2000 lbs.
Carburizer	140 lbs.
Ferrosilicon 50 per cent	80 lbs.
Ferromanganese 80 per cent	10 lbs.
Electrodes (graphite	10 lbs.
or carbon)	24 lbs.
(Limerock	150 lbs.
or Lime)	75 lbs.
Fluorspar	20 lbs.
Power	750 kwh.

At first glance it would seem that in this estimate no allowance has been made for melting losses. However, when one considers that about 3.5 per cent of carbon, 4 per cent of ferrosilicon, and 1 per cent of ferromanganese will be added to the metal, it will be seen that in reality

a loss of 8.5 per cent has been allowed. Our experiments have shown that, when starting with a hot furnace, a carbon content of 3.75 per cent can be obtained with a power consumption of 650 kilowatt hours per ton, as indicated by the watt-hour meters. In the estimate, 750 kilowatt hours are used to represent the power consumption based on the maximum demand. Lime and fluorspar will be required only when the scrap contains much sulphur or is contaminated with siliceous material. The time of melting will vary with the power input to the furnace but will ordinarily be from 1 to 2 hours, and the carburization period from 30 minutes to 45 minutes.

Summary

1. The manufacture of synthetic foundry iron is a proved technical possibility and is readily conducted if certain methods of operation are followed.

2. Practically any grade of iron or steel scrap can be used.

3. Synthetic foundry iron can be made in standard commercial electric furnaces either as the sole operation of the furnace or in alternation with other melting operations.

4. Rapid carburization and high-carbon content can be obtained by maintaining good contact between carburizer and metal and operating at a high temperature (at least 1400 degrees Cent.) Best results are had with low-ash carburizers and in the absence of slag. Siliceous slags are detrimental. If high-ash coke is used, the ash should be fluxed with lime and the slag removed.

5. Synthetic foundry iron of exceptional purity can be made and its composition can be readily adjusted to fill any specifications. If cast direct, it will have the desirable properties of electrically-melted iron, such as strength, toughness, and fineness of grain.

6. Synthetic pig iron can compete with blast furnace iron in localities where high freight rates or other causes make the blast furnace product expensive and where power rates and cost of steel scrap are low.

7. The most economical method of handling the synthetic iron is to pour directly into commercial castings. By this method the synthetic iron can compete with blast furnace iron that must be remelted, even where such iron is relatively cheap. The increasing tendency toward electric melting of foundry iron and the possibility of using cheap scrap metal as a raw material make the manufacture of synthetic cast iron particularly attractive at this time.

8. If the process should become commercially practicable in any foundries of the country, it should be a definite influence toward better waste elimination. There will be less transportation of scrap over long distances, and much of the poorest iron and steel scrap will be recovered in a high-grade product.

Discussion—Synthetic Iron

J. T. Marsh.—I carried out some experiments about three years ago in a furnace with synthetic iron and found some difficulty in obtaining the desired combined carbon. Some of the carburizers used were slow in giving carbon values, and I wanted to ask Mr. Sims if he carried on these experiments long enough to get control of the carbon values.

C. E. Sims.—Combined carbon was controlled more or less with the silicon content.

J. T. Marsh.—Were you able to introduce silicon in such a manner as to control that combined carbon?

C. E. Sims.—We have not made any experiments on that particular point, but we always found that with the proper silicon content and slow cooling, such as there would be in the sand casting, it has been very uniform according to the silicon content. We have very high recovery of our silicon so that by

measuring the silicon we put in we can control the amount we get in the iron.

J. T. Marsh.—I found in my experiments that the combined carbon varied quite a good deal from a point running around 0.41 down to as low as 0.10. There was quite a variation.

C. E. Sims.—We have found that the sulphur is one thing that affects that considerably. We have found that when we had our sulphur high the influence of the silicon was neutralized but if we get our sulphur out or down low, about 0.05 per cent, the silicon is very consistent in its action.

J. T. Marsh.—I was using boiler scrap and did not add any sulphur. Another question; did you find an equal distribution of the carbon on spots where there was most graphitic carbon than in other spots? Soft spots?

C. E. Sims.—We only found that when we ran up to very high silicon, up around 7 per cent silicon, we found then large pockets containing considerable graphite.

J. T. Marsh.—Several gentlemen lately to my knowledge got very soft iron in the electric furnace. I had two electric furnaces that I experimented with for years and I noticed that where I ran the carbon to the saturation point, and endeavored to throw the combined carbon very low and the graphite carbon very high, I had those spots you speak of.

C. E. Sims.—That comes from either a very high silicon or very high carbon. If you get a hypereutectic iron running over 4.3 carbon, it precipitates out so rapidly during solidification that there is an excellent opportunity for segregation.

G. K. Elliott.—Mr. Marsh brought up the subject of silicon which is interesting. A year ago I stated, at the Electrochemical society, that I thought that electric furnace iron, especially the basic, required a higher silicon for a given degree of hardness or softness than did iron of the same analyses coming from the cupola. That is, if two per cent silicon gave you the hardness you wanted in the cupola, you might have to run it up to two thirty or two forty in the electric furnace to get the same degree of hardness and I finally came to the conclusion that the whole matter centered about some of the gaseous elements present

in cast iron, which the analytical chemists at present seem unable to determine for us, especially carbon monoxide and carbon dioxide. Some Japanese investigators several years ago reported that the presence of the gases had considerable to do with the precipitation of graphite from white iron which had a catalytic action, and I believe that the presence of these gases in the cupola metal assists in some way in the precipitation of graphite, whereas in the electric furnace, especially the basic, these gases are probably largely eliminated and we have not the same catalytic agents in there for the precipation of graphite from the combined carbon, I established that hypothesis and so far I have not found anything to upset it and I am very much interested to hear of Mr. Marsh's experiments.

J. T. Marsh.—Then at that point, Mr. Elliott, don't you find that very often the manner in which you cast, the casting temperature and the sprue you have on there, have influences and the design of the mold has something to do with the graphitic carbon.

G. K. Elliott.—It probably has a great deal to do, because they have an influence on the solidification, if nothing else and that is one element in determining the condition of your carbon, the time of freezing.

J. T. Marsh.—I cast all my test pieces in sand and taper them about two inches at the top and at about two inches long and an inch and a quarter at the bottom, and allow them to cool without any sand over the top, but with a view of getting a comparable condition, rather than a research condition, I found that in casting with white iron many times, we got 0.04 or 0.08 graphitic carbon; but I rather figured at the time that there were other conditions there that I was not controlling properly and that was a thing I wanted to find out whether it was possible to get a proper proportion of silicon by the use of ferrosilicon and a carburizer, as far as a carburizer that would enter the iron and the silicon could control that carbon going in there. As I said a while ago, I found my combined carbons were all over the sheet, they did not run any two days alike, although I weighed up my boiler scrap carefully and everything that went into that iron, measured them carefully and took every pre-

caution to get the analyses as much alike as it was possible to do. That is a laboratory proposition, but if you cannot do it in a laboratory I was wondering if you could do it in practice. If there is a possibility of holding that silicon in the electric furnace or some manner of introducing it at some period in the melting, whereby you get a uniform practice, I do not think it is impossible, but I think it is a mighty good line of research. I have been at it now about two years, and I am not making a whole lot of headway on that proposition.

G. K. Elliott.—I would like to ask Mr. Marsh if he is operating acid or basic?

J. T. Marsh.—Acid: I started with basic and went to acid; I was using very low sulphur and manganese scrap.

Mr. Osborn.—We have been experimenting along the same line, but cannot lower the combined carbon by adding ferro-silicon.

A New Long-Life Mold Development

By Dr. Richard Moldenke, Watchung, N. J.

The foundryman has always felt that the destruction of the mold every time a casting is poured is an inefficient procedure. Indeed, the making of molds which could be used over and over again dates back to the bronze age, when implements of warfare and domesticity were made in stone molds the two parts of which were suitably hollowed out, clamped together and poured much as our present brass ingots. These stone molds are in reality the first "long-life" molds on record. In the development of the iron industry, with molten metal at first only as an undesirable occurrence in the operation of the small blast furnaces used, the open-sand mold was the only practical means of caring for the intermittent supply of metal. As time went by, however, and the iron foundry became stabilized, the desire to construct molds which would last for more than one filling without damage asserted itself again and as early as the opening of the last century we have English patent records bearing upon the subject.

While the iron mold—or as we know it under the title of "permanent mold"—has been known and used for perhaps a century and a half, and is today attracting world-wide attention in connection with the centrifugal casting process, the method in its simpler forms has never found a solid footing in the foundry industry, the fundamental reason being that the molten metal when poured into an iron or steel mold is subjected to entirely different influences than is the case with the ordinary sand mold. The rate of cooling is so much faster, with consequent more sharply defined crystallization effects and production of very fine grain structure if not actual chilling of the metal to whiteness. Even where the attempt is made to approximate the rate of cooling as in the sand mold, by suitably preheating the iron mold, this either falls short of the desired situation if the mold is to last, or when preheated sufficiently

pouring must be done at longer intervals unless the life of the mold is to be sacrificed. The consequence has been that while good castings have been made with all the permanent mold processes brought out, the irregularity of product unless corrected by careful and costly annealing has militated against their commercial success.

For ordinary work, therefore, it seems far better to return to the old bronze age idea of using the equivalent of the stone mold—in other words, a mold of the refractory surface properties of sand and yet strong enough to yield a large number of acceptable castings before considerable redressing is necessary or the mold must be discarded. This would be the "long-life" mold. Coming down to practical considerations, the following conditions would seem to be indicated in developing such a type of mold.

Conditions to Be Considered in Developing Long-Life Mold

First:—The mold surface must be of a highly refractory character so that the least possible heat may be transmitted inward to affect the form of the mold as well as seriously limit the rate of pouring iron for castings into it. If too much heat passes from the surfaces in contact with the molten iron into the body of the mold, the very purpose of the mold is lost, as it no longer will approximate the regular sand mold. Again, a too hot mold will warp and deteriorate rapidly. Hence the desirability of having the mold light and if necessary air cooled, so that the mold body may not accumulate heat unduly and thus affect the rate of pouring detrimentally. The ideal situation is that of the heat conditions in the green-sand mold from which the casting has been removed just after setting—imagining this possible without destroying the mold. But a very small depth of sand will have been seriously affected by the extreme heat, and the outer portions of the mold may still be cold.

Second:—The nature of the mold material must be such that no gases are formed during contact with the molten metal, until this has set. There is little chance for venting in such a mold. A momentary consideration of this matter, however, will

show that after all it is the fault of the mold if gases are formed which affect the metal surfaces. The chilled roll is a case in point. Here is no chance for venting whatever, and yet castings are made which machine up without a defective speck. Further, it is perfectly possible to cast against a fire-brick surface successfully, provided the surfaces are perfectly dry and preferably warmed. Hence, if the casting surfaces of a long-life mold are of a finely granluar and highly refractory nature there need be little fear of bad results due to lack of venting.

Third:—The mold surfaces must be sufficiently strong to resist the cutting action of the molten metal, and be impervious to the entrance of fine filaments of iron which on removal of the casting would take some of the mold material with it. Further, the mold surfaces must not spall off. If thoroughly dried the last named action should not eventuate. The strength of the mold surfaces is a question of the bond, and the porosity of the material a matter of the fineness of grain or crystal.

Rate of Removal of Heat From Molten Metal Must Be Considered

The crucial point in the above considerations as to the nature of a desirable mold surface is the rate of removal of heat from the molten metal—whether as slow as in the case of the ordinary sand mold, or fast enough to permit some chilling action. This rate of removal of the heat until the molten metal has safely set depends upon the refractoriness of the material in greatest measure, the temperature of the molten metal and and quantity of metal involved, as also the freezing point and other metal characteristics. For the various sections of a casting the temperature of any point of contact between mold surface and molten metal will be practically the same at first, but the depth to which the comparatively high temperatures will penetrate the mold mass will naturally depend upon the thickness of the metal which has to set against it. Thus, if in a casting, that portion one quarter inch thick imparts say 1000 degrees Fahr. to a point 1/64 inch within the mold mass, another portion of the same casting, 2 inches thick may show

the same 1000 degrees Fahr. at a point 1/16 inch deep within the mold mass before the metal has safely set. Practically tor "long-life" mold purposes, it is the nature of this 1/16 inch or less depending upon the thickness of the castings to be made, that must be carefully considered and conform to the requirements above enumerated. The rest of the mold mass can be any material that is structurally safe to hold the refractory surface true and well bonded, and will also absorb the heat passed through the mold surface material and promptly dissipate it. In other words, a cast iron backing to a refractory mold material forming a contact surface for the molten iron, is an ideal combination when the refractory facing of the mold is heavy enough to transmit heat at the proper safe rate, and the iron backing is light enough to dissipate the heat transmitted into it quickly.

A Practical Long-Life Mold

With the above underlying principles involved in the construction of the "long-life" mold thus enunciated, it is the purpose of the writer to show how the problem of adapting these principles for everyday practical application have been worked out into a system by the Holley Carbureter Co. of Detroit, and to show illustrations of the machines built for the purpose. When it is stated that by this time some of the molds have already had ten thousand castings made in them and by reason of a close daily inspection of and attention to the refractory facing material of the molds not one of them has yet had to be discarded, the writer feels that here is truly a new development in making long-life molds. The term "long-life" is used advisedly as against "permanent," for in the latter the supposition is that no repairs are made on the metal mold; whereas in the former, repairs are possible and are carried out until they no longer pay.

The system devised by the Holley Carburetor Co. has been carefully worked out in every detail and is fully patented. The several steps and the reasons for operating just that way are given in the following:—As previously indicated, the primary idea has been to make a very light cast iron mold, the

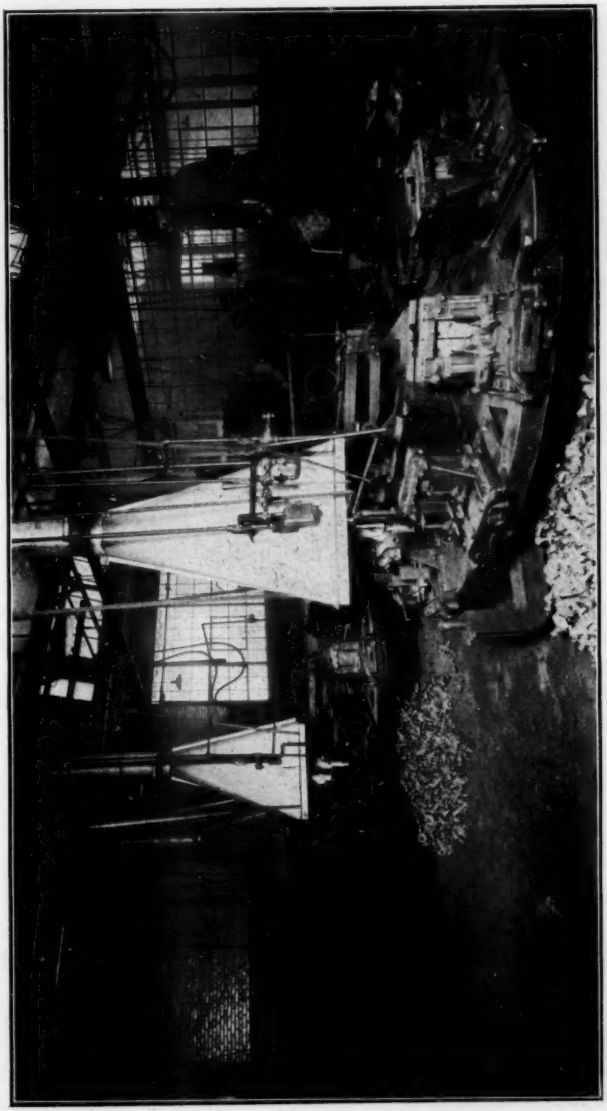

FIG. 1—GROUP OF LONG-LIFE MOLDS ARRANGED ON THE REVOLVING TABLE FOR POURING

surface of which is covered with a layer of highly refractory material, of necesary thickness, and this refractory material so protected from abrasion and penetration of fine iron filaments, that it almost wears to a polished surface and only on rare occasion needs to be patched up or refaced. For operating purposes, where the castings are not large, a group of molds are placed upon a revolving table and the several steps of the cycle can be carried out almost completely automatically. Where the castings are larger and a table of three to eight molds would be cumbersome, single molds would be operated as long as molten metal is available.

Refractory Material Forming Mold Lining

The refractory material forming the mold surface consists of two items, the refractory material itself, and the binder to bind it to the iron backing. The refractory material can be any of the usual substances used to resist heat in the arts. Thus, magnesia, bauxite, fire-clay or kaolin will serve. The grain must be exceedingly fine and in the application heat must be used finally so that no question of gas forming constituents remaining in the mass may arise. The binder must be a mineral one, an alkali silicate being most convenient, so that when heat has been applied the mass is like a thin sheet of stone. The material is preferably put on in comparatively thin layers, and each one baked on before the next is applied. For the heavier facings, the final layers can be applied by transfer from what would be a metal pattern, so that the accuracy of the finished long-life mold leaves nothing to be desired.

Molds Can be Operated on Revolving Table

The final heating—in effect a skin-drying at temperatures to almost vitrify—being accomplished, the molds are placed in their proper position on the revolving table, and successively follow their prescribed course. In passing around, the two parts of the mold are drawn apart sufficiently to allow the settling of cores, but just before this each mold successively passes a flame of acetylene gas which smokes the inner surfaces heavily. The idea of this is to interpose a film of carbon between the refractory surface and the molten metal of sufficient

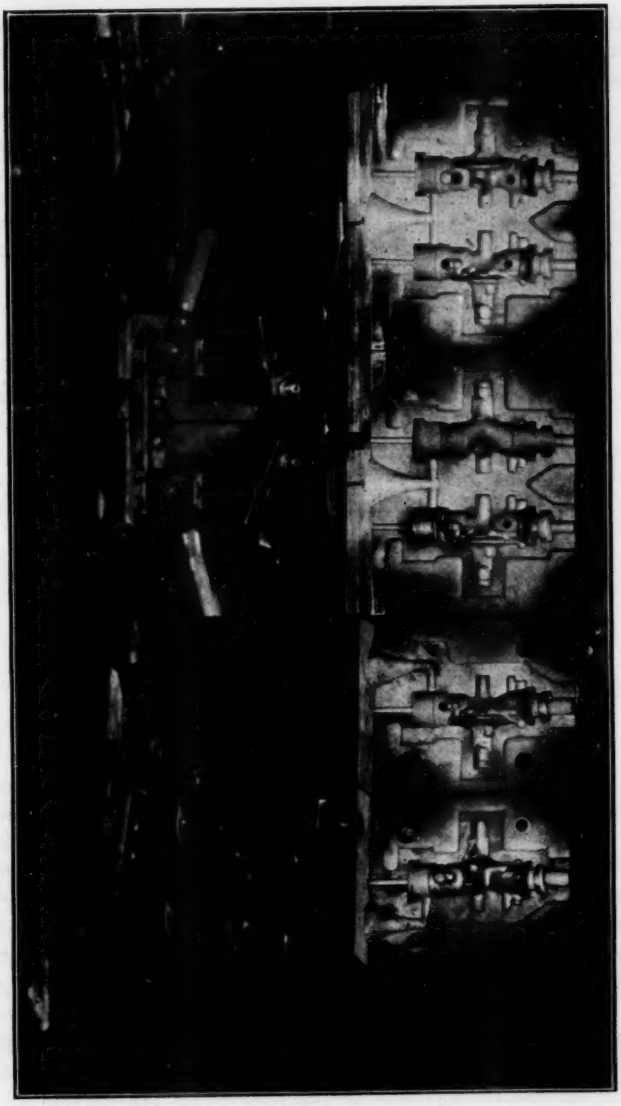

FIG. 2—A CLOSE-UP VIEW OF THE OPEN MOLDS. A CORE HAS BEEN SET IN THE THIRD MOLD FROM THE LEFT

strength to effectively prevent any scoring action or the actual contact of metal and refractory material at the instant of greatest temperature effect.

Most of the carbon is absorbed by the metal, but the effect is that until the molten metals is no longer dangerous, the refractory material is protected. After passing the flame and the position where cores can be set, the two parts of the mold are made to close automatically and are held thus until poured off and the metal has sufficiently set. Then they quickly open and the castings are forced out by pins or in other suitable ways.

Cooling and Cleaning The Molds

Next, a blast of air at high pressure rapidly blows the surfaces clean and the mold passes before the acetylene flame again. The man setting the cores, or in their absence, any attendant watches out for the mold surface condition as the molds pass be open, and any fragment of iron or core left in the mold is easily removed with a suitable tool.

The iron backing of the mold has been stated as comparatively thin. This allows—particularly if constructed with that in view—the use of air-cooling action. Where such an air blast for cooling the iron molds a little faster than they would normally is in use, the machine can be speeded up and thus give a larger production.

Method of Pouring

Whether pouring is done by hand or from suspended ladles; whether the man remains stationary while pouring as the mold passes him or a moving platform accompanies the table; whether the molds and cupola are together or iron has to be carried from a distance; and lastly, whether molds are poured all day long or merely the usual two or three hours, depends upon the individual situation. It may be of interest to state that with twelve single molds on the revolving table, one man can pour 400 castings of a given kind per hour. With sand casting it takes eight times the number of man-hours to get an equal number of the same kind of castings. Further, from the nature of the pour-top pour—it is possible to feed

the molds more perfectly and hence the castings made are quite free from shrinkage even with considerable variation in sections. This makes for denser metal and the consequent benefit to strength conditions and wearing qualities.

Method Can be Developed

While the process is still in its infancy and attention has naturally been give to quantity production of the comparatively light castings required at the Holley Carbureter Works, nevertheless many automobiles pistons have been made also, and these involve somewhat thicker sections. It will become a matter of heavier refractory coatings, and more frequent repair of exposed points in these coatings, when larger work is undertaken.

Construction Features

Of the illustration given, Fig. 1 shows a group of long-life molds arranged on the revolving table and ready for the pouring operation. Directly at the right end of the wooden platform the mold will be noted just closing up. The next five molds will be seen as closed. Pouring is done while the molds pass the wooden platform. The metal sets properly while the table brings the molds successively to the position of the one under the last pipe at the left, where the molds open for the ejection of the castings. At the next position toward the right the mold face is blown clean, then it comes before the acetylene flame as seen directly under the hood. Here the mold face is smoked, the excess smoke being drawn away with the products of combustion. The molds are now wide open and at the extreme right of the table three molds can be seen fully open for inspection and the setting of cores. The cycle then repeats itself.

Fig. 2, shows the molds more plainly and also has placed in the foreground a set each of a one and a two-casting mold. The arrangement for pouring basin, core vents and gating is plainly shown. A core has been set in the third mold from the left. The holes in the molds directly in the spaces for the molten metal are filled with suitable pins which push inward as the molds open and thus eject the castings automatically.

Fig. 3, shows some of the castings as ejected from the molds and partly machined. Also a broken casting with perfectly uniform, fine-grained fracture, easily machinable and without a sign of chilling. The piston casting shows some thick sections, not being cored for the pin. The pair of castings connected with the gate, at the extreme right, are interesting as being taken from the right-hand pair of molds of Fig. 2. The cores have been removed.

Fig. 4, shows two of the tables in operation. Pouring off may be observed on the first table, and the smoking of the

FIG. 3—CASTINGS MADE IN LONG-LIFE MOLD. SOME AS EJECTED FROM THE MOLD, SOME AS PARTLY MACHINED

molds on the first and second. Successful results have also been obtained by spraying the molds with a film of graphite in oil, the heat of the molds driving off the oil almost immediately. This method would doubtless be more economical for larger molds.

It has been of great interest to the writer to observe the operation of the Holley development. For many years he has advocated leaving the "permanent mold" idea in favor of the "long-life mold," as giving promise of better results, if not as spectacular. The principles involved have also been discussed by the writer, but until the Holley Carbureter Co. had worked

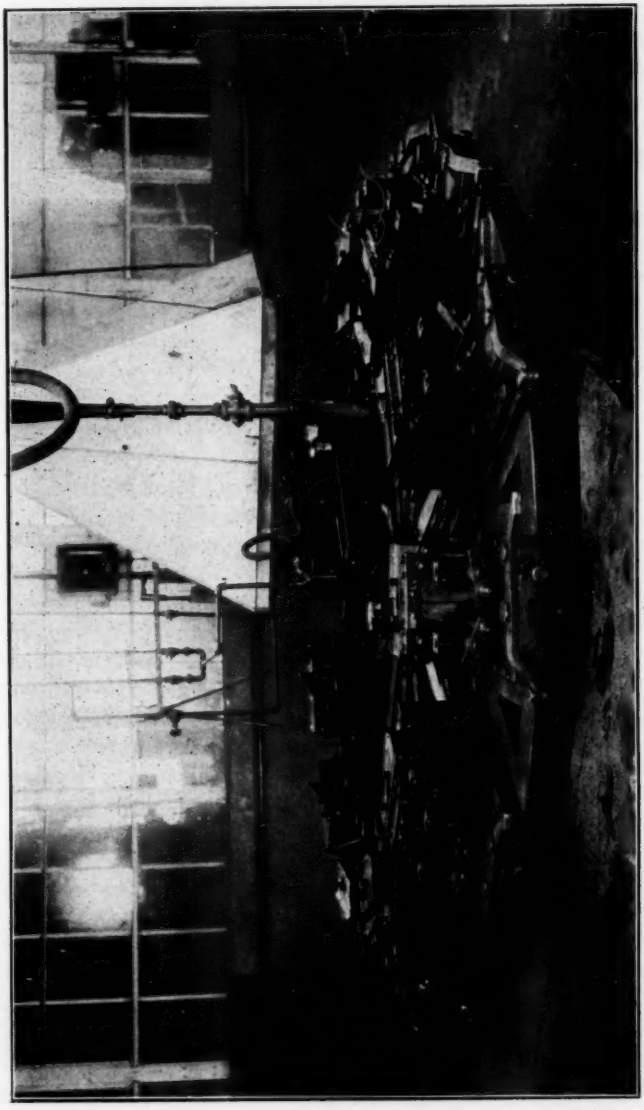

FIG. 4—TWO POURING TABLES IN OPERATION

out the problem step by step and had provided for the several contingencies mentioned in connection with the requirements of the mold surface, nothing comprehensive in this line had come before the foundry industry. It is with genuine pleasure, therefore, that there has been given as the title of this paper the words "A new Long-Life Mold Development."

Desulphurization of Cast Iron

By Dr. R. Moldenke, Watchung, N. J.

One of the most serious problems confronting the foundry is that of a constantly increasing sulphur content in its scrap supply. With every remelting of iron in cupola or furnace, sulphur is absorbed from the fuel and the resulting molten metal runs from one to five hundredths of a per cent higher in this undesirable element. The greater part of the foundry product sooner or later finds its way into the country's scrap piles, and with ever greater percentages of this scrap going into the daily foundry mixtures, the sulphur problem is gradually becoming acute.

At the time of his entry into the foundry industry, in 1890, the writer remembers that his first analyses of various pieces of characteristic scrap showed a composition of about 0.05 sulphur. Comparison of data with friends who had been making the laboratory an important and indispensible adjunct to steelmaking at the time confirmed this situation. As the years went on the constant remelting of our scrap supplies ran the sulphur average higher, so that by 1900 the sulphur had nearly doubled. At any rate, the first specifications for cast iron products recognized 0.10 sulphur as allowable for heavy castings. And still this sulphur increase went on, so that by war-time 0.14 was a common situation. The upsetting of all standards of practice during the war, when through absence of pig iron periodically scrap proportions soared up to 90 per cent in a mixture, and oftentimes no pig was used at all, has meant a probable present average of 0.18 sulphur in our scrap, with the worst yet to come when the war castings finally arrive in full force. Thus will the scramble for dollars regardless of consequences be followed by the usual costly reckoning such a method deliberately invites.

In ordinary normal foundry procedure an undue sulphur content in the daily work is prevented by the use of as large

a pig iron percentage in the mixture as may be economically possible. From the nature of the blast furnace process it is possible to get pig irons with reasonably low sulphur percentages, so that the problem becomes one of diluting the sulphur in the scrap and that added during the melting. Unfortunately, this ordinary normal procedure is not possible at the present time, for pig and scrap percentages are such that an increase in sulphur results in spite of the dilution in question and castings with sulphur up to 0.25 are of common occurrence. It is to be hoped that the normal procedure of today is an extraordinary one, and may revert to the ordinary again in not too distant a future.

All foundry remelting processes are more or less oxidizing in character, and hence due allowance is made for losses in those elements easily affected. Silicon and manganese are the two chief objects of attack by the oxygen of the blast, so far as the metal itself is concerned. Using suitable pig irons rich in manganese cares for that element, and the silicon is calculated out specifically to be certain of the proper result. In the case of sulphur and phosphorus, however, the first is enriched by absorption from the coke used, and phosphorus practically concentrates as none of it is lost in the reduction of tonnage during melting.

Reduction of Sulphur in the Blast Furnace

While sulphur is now understood to be less injurious than was formerly supposed, for most of the evils attributed to it may be charged to oxidation of the iron through poor melting; yet as present day melting practice is only a striving after perfection in method, with every foundryman falling less or more behind the ideal, the combination of high sulphur with some oxidation of the metal itself becomes an unmitigated nuisance and leaves a trail of lost castings following it. Hence the elimination of sulphur in cast iron is a very pertinent, timely and practical problem, the first and easiest solution for which lies in the use of high percentages in the mixtures, as above indicated. Another method of sulphur reduction applicable to cast iron prevails in blast furnace practice and is efficient because of several factors. First the comparatively higher heat of direct

metal, where time is plenty and where in transportation there is considerable jolting. In such a case sulphur and manganese get together and the compound, readily formed under temperatures so much higher than cupola metal, gets jolted upward under and into the slag, and can be removed before pouring the iron into the casting machine for pigs. Remarkable sulphur reductions are the result of such a procedure. Unfortunately, however, the foundry has neither the temperature nor time available, nor does the foundryman wish to jolt his molten metal during transport.

The Electric Furnace for Desulphurizing

The second method for desulphurizing cast iron, and unquestionably the best one, is treatment of the molten metal by lime additions upon the basic hearth of the electric furnace. Practically all the sulphur can be removed from cast iron in this way, if time and expense be a secondary consideration. "Duplexing," or running cupola metal into the electric furnace for additional superheating, with possible deoxidation, and reduction in sulphur as desired, is now well-known in the foundry industry, so that special attention need not be given the subject here. The fact remains, however, that an electric furnace is costly and hence within the reach of larger concerns only; and furthermore furnace operation costs also, the principal items being current and electrodes. Nothing in the method to be described below should be construed as antagonistic to the electric furnace process, whether straight or by duplexing, but the great majority of foundries find it, and always will find it impossible to undertake this costly but wonderfully effective method of getting the finest cast iron that can be made at the present day.

Reduction of Sulphur by Chemical Additions

The latest candidate for foundry favors in regard to sulphur reduction in cast iron is the chemical method. It has long been known that the application of soda or potash on the clean surface of molten cast iron will remove considerable of the sulphur contained. Many foundries have tried this out but have always given it up because of the irregularity in results and the time consumed. It has remained for Richard Walter,

at Dusseldorf, to discover just how to apply soda, or other alkali-earths, so that positive and practical benefits are derived from their use in the way of sulphur reduction in molten cast iron. It was in the little details of this known method that improvement was effected, and an inexpensive and easy way of reducing sulphur to a commercially practicable point evolved. The writer first saw the desulphurization of a ladle of molten iron by the Walter process—the first practical one in existence at that time—at the Krupp works in Essen, in 1921. On his return to the United States he described the process and gave details before bodies of foundrymen. Since that time half a dozen methods have come into use in Europe and several over here, and there is nothing to hinder any foundryman from making his soda cakes for desulphurization purposes. Walter, however, found that the most successful application of the chemical method was had by adding small percentages of the alkali-earths, notably barium or magnesium, to a soda and potash base, and this combination he has patented widely over the civilized world. Referring again to the Krupp test observed, the writer took a sample of the metal before applying the desulphurizer, and again another one after the metal was ready to pour into work. On analysis here, the sulphur was found to be 0.14 reduced to 0.095, or 32 per cent. From tapping out to finish of the test six minutes had elapsed, the usual time for contact of the desulphurizer with the metal being from two and a half minutes to four, depending upon the temperature available.

Difficulties Encountered in Developing Methods

In developing the method, Walter found that the chief objection to the use of soda ash on molten iron was that it took too long to melt. The writer had seen cakes of compressed soda ash sold here for the purpose which have not been satisfactory because of this difficulty. The air films between the individual grains of soda are sufficient insulators to prevent heat passage through the mass and the result is that such cakes float on the iron and melt but slowly. The first little detail solved by Walter was to melt the soda base to remove all these air films and thus get cakes which would melt very rapidly when thrown on the

molten iron. The next thing found was that unless the surface of the molten iron was thoroughly cleaned from the slag floating on it, the reaction would not take place. The alkali simply united with the silica of the slag, and the sulphur was not affected. This meant that a ladle of molten iron has to be skimmed off carefully and fully before the desulphurizer cakes can be thrown on. Obviously this means carefuly cupola practice to run very hot and thus get a clean separation of iron and slag within the cupola itself. Then, in tapping out, to "bot-up" before the slag begins to run. Again, it is necessary to keep the ladles clean, and most important, to make iron which will not have more slag come to the surface after cleaning off once. Such iron—which is often seen in foundries with poor melting practice—is hopeless of improvement, for the soda-slag greedily attacks the iron slag and any sulphur absorbed by contact at once returns to the iron. Observations have shown that only the liquid slag of the iron is to be feared specially, as the ladle lining itself is attacked so little in the short time involved that contact with the brick and daubing is negligible. Further, the practice of throwing a handful of sand on the clean surface of the metal, whether before applying the desulphurizer, during the reaction, or just before removing the soda-slag, must not be resorted to as it will vitiate the effect at once.

Removing the Slag Formed by the Desulphurizer

It is, of course, possible to throw the desulphurizer cakes into the bottom of the ladle and let the stream of molten metal flow over them as the ladle fills up. This saves a lot of time and is to be recommended where provisions are made to keep out slag absolutely; and further, where the iron is so hot that chances for soda-slag mixed up in the iron when pouring off the metal are not taken. This soda-slag of the reaction is an exceedingly thin and penetrating material. If allowed to run into the molds with the iron the castings are doomed. Hence, the next little detail worked out by Walter was to provide for an effective way of removing this thin slag. He does it by scattering a highly refractory absorbent material upon the thin slag and thus solidifies it whence it can be broken up with the rod or skimmer and easily removed. The best material

is air-slacked lime, which is a fluffy powder that sucks the thin slag right into it and solidifies in lumps, so that the surface of the ladle after application of about a cigar-box full of lime to a ton of metal looks like a clear ocean of liquid, clean metal, with floating islands of chalk dotted over the surface. Tilting the ladle and using the skimmer makes a clean job and the metal may now be poured. If, however, the metal is still very hot and it is desired to repeat the operation, this can be done and another reduction in sulphur effected. Normally the reduction is forty per cent so that sulphur 0.18 should be cut down to 0.115 or better. A second application would normally reduce this further to 0.07, or better. So that the result is a very valuable one considering the beneficiation of the metal achieved.

It may be stated, that if desired, this powdered lime can be merely thrown about the lip of the ladle, and the slag thus consolidated only about the pouring point and effectively holding back the thin soda slag behind. Preferably, however, the slag ought to be removed in toto, as there is always a chance of stray slag being about, and this means a reversal of action.

Amount of Desulphurization to Use

Walter found the quantity of material to be used for results that are good and at the same time not too costly, is half of one per cent of the weight of the iron to be treated. That is to say, ten pounds for every ton of metal for every treatment given. In many cases it is possible to make two applications and wind up with metal still hot enough to pour successfully. A little further down, however, the writer will give what he thinks the method which will be used in America, as ladle treatment is not a very popular procedure here.

Chemical Combinations Tried Out

The imitations of the original Walter development have run into some curious combinations of chemicals. The use of potash and soda, with some barium and magnesium salts, when melted and poured into cakes, yield a material which will melt on the molten iron quietly, without fumes or flame and throw off no gases to injure the respiratory organs of the operatives.

In one imitation, a proportion of caustic soda is added to the soda base, and this is claimed by those who have used it to be very disagreeable by reason of the highly caustic and irritating particles thrown off when struck by white hot molten metal. Again, chemicals other than those of the alkali groups when thus used have only a part of the action in removing sulphur. Indeed, probably all the materials offered to the foundryman give a certain effect at the first few moments of contact, but this effect is only sustained where the alkalies are used.

Reaction Extends Throughout the Ladle

A further very interesting fact is that the reaction of the desulphurizer placed on the surface of the metal in the ladle extends promptly through the whole mass. Samples for analysis have been repeatedly taken from the top, middle and bottom of a ladle of desulphurized iron and practically identical amounts of sulphur found. Again, many tests have been made to observe the action of the alkalies on any gases that might be dissolved in the metal, and in every case these have been found materially reduced, showing that there is a slight tendency to deoxidation. These investigations are being conducted in Europe and the data obtained will eventually be published.

Probable Application in America

The method that will probably be used in America in applying desulphurizers to molten iron, is one that is already giving excellent practical results in some European foundries. It consists in arranging for a slag-removing cupola spout, either for all the metal tapped out, or having such a spout in addition to the regular one and specially for the purpose in hand where it is desired to desulphurize only the metal for special lines of castings. This special spout has a trap arrangement close to the tap-hole, the molten metal passing under a firebrick bridge which retains the slag that may come with the metal and lets it flow over a notch in the side. It is a spout often used where the stream of iron flows continuously. In case of stopping-up, if the basin of molten iron under the firebrick arch is apt to freeze up, this metal has to be tapped away by special tap hole. The stream of metal from this special spout is allowed to run into a large storage ladle which has a partition at the lip

which runs almost to the ladle bottom. In other words, the ladle is in effect a "tea-pot" arrangement perfectly familiar to all foundrymen. When full of metal the bulk of the molten iron is in the large chamber with but a little in the "spout" portion of the ladle. On the large surface there is placed sufficient desulphurizer to start the reaction, and this is added to from time to time as the iron keeps flowing into the ladle and as metal is poured off into the carrying ladle. The proportion of desulphurizer added is aimed to be the standard half of one per cent of the molten metal to be treated. When running along in this way, every so often the adding of the cakes is stopped and air-slacked lime is thrown on to collect the spent soda-slag; and this is removed just as in the case of ladle treatment. There need be no cessation of the stream of metal entering the ladle nor the taking away of the corresponding amount by tilting it into carrier ladles. The object of the method is to create as little interference with the shop routine as possible.

Where all the molten iron is to be desulphurized, the apparatus can be of considerable size, so that it in effect serves as a forehearth for the cupola. This will undoubtedly be the future development, for with a continuous stream of iron from the cupola, and this carefully cleared from slag automatically, with a large mixing ladle to serve for storage and desulphurization action, there will be no necessity for holding metal in the cupola at all, and the tuyeres can be lowered considerably while still allowing for regular slagging-off. Coke is thus saved and a better chance for mixing given the metal than is possible within the supola.

It is a curious fact that whenever a need presents itself in an acute way, a remedy comes to hand. Foundrymen have looked with misgiving at the evident dying out of the skilled molder, but the mechanical equipment devised seem to have replaced him fairly well without the promised disaster. So also in the case of the rising sulphur in our scrap, we are given two very effective ways of correcting the difficulty, and the method above described seems to amply fill the requirements of the foundryman unable to purchase the electric furnace with its still greater possibilities.

Discussion—Desulphurization of Cast Iron

A Member.—I am glad to hear Dr. Moldenke explain this sulphur problem, because I am afraid there are some firms putting things on the market, which, unless foundrymen are pretty well informed on the subject, will give them some trouble. I would add that there are substances that not only take out sulphur, but that take out quite a number of other substances. I think Dr. Moldenke's explanation of the use of soda ash will be very well appreciated by the foundrymen.

Mr. Rayner.—We have been using soda ash for about a year. The primary reason for using it was to eliminate defects in the casting, and we found in analyzing the slag in that casting there was manganese sulphide in the bottom of the ladle, which causes a flare-up but not dangerous. We find it softens the iron by oxidizing the slag, which is so much thinner that it runs through the gate. The silicate sand seems to work this way.

Leon Cammen.—I think I might answer this question about hardening of the iron. The action of the soda ash is a solvent reaction. If your metal has very little sulphur, you will attract silicon. If the amount of sulphur is too high there will remain a very vigorous combination, and you will have little bits of this material picking up the silicon depositing sulphur, but not returning the silicon to the metal. Now if you want to check up this reaction, try this out. Put a heavy slag on top of your metal—preferably in the electric furnace—take a nonsulphur iron and add to it the soda ash and you will see the same remarkable reaction.

Mr. Ramsey.—I would like to ask Dr. Moldenke if any information is available which would indicate the depth to which this reaction takes place in the ladle—having in mind the 35-ton ladle.

Dr. Moldenke.—That was tried out at the Bethlehem Steel Co. and they got 25 per cent. No matter what the size of the ladle, the reaction is complete.

Mr. Joseph.—I have occasion to know of a firm that is using this substance in connection with steel castings. They are taking the sulphur out all right, but the castings didn't stand up for the bending test.

Dr. Moldenke.—Well, maybe they didn't get the slag all out. Probably there is some little cause there. We will know more about this in another year.

Mr. Dorry.—We have made experiments in making car wheels.In pouring our wheel blocks we found we increased the depth of chill. We got it before and after putting in this preparation. After the wheels went through the annealing process and were physically tested they stood a better test than any wheels tested before.

Dr. Moldenke.—You tried separate ladles, didn't you? Now some day try this continuous operation.

Heat Treatment of Alloy Steel Castings

By A. W. Lorenz, South Milwaukee, Wis.

The heat treatment of steel castings is no longer a matter of curiosity and speculation, but is a practice well established in many of our leading industries. Strange to say, it is a matter which has not been taken up seriously by foundrymen in general, possibly because they do not as a rule have either the equipment or personnel for such work. The development of heat-treated castings has been confined almost entirely to those manufacturers who, by reason of their experience in the treatment of forge and tool steels, are in a position to handle castings as well. The ideal condition should exist, however, when the foundry is equipped to deliver fully treated castings, for while heat-treatment alone produces a certain amount of improvement, the best results can only be obtained when foundry practice ties in with same.

Heat Treatment Emphasizes Good and Bad Properties

There is a simple explanation for this, in that heat treatment exaggerates to a remarkable degree the virtues and failings of the steel itself. One investigator has expressed the opinion that the heat treatment of steel castings will bring on a new era in foundry practice, focusing attention on things heretofore considered of little moment, and calling for higher standards of quality. It is not the purpose of this paper to go into detail on such points, but we shall enumerate briefly some of the defects which are becoming apparent to the treater of castings.

(1) *Non-metallic inclusions.* This point has been thoroughly discussed by various writers. Possibly, however, too much attention has been focused on the contained or self-generated impurities of the steel itself, such as manganese sulfide, alumina, etc., and not enough thought has been given to the inclusions picked up in the mold. Excess silica wash, drops and breaks due to poor ramming, or dirt carelessly left in the

mold, are the most harmful things imaginable in a piece of steel. Such impurities form a film between the crystals, and no amount of treatment can remove the outline of the original structure. Surface inspection of a casting may be a better criterion of quality than many a physical test.

(3) *Dendritic structure.* This is sometimes so pronounced that the most careful treatment will not remove it. This structure is held to be due, as one investigator states it, to the temperature gradient between the center and surface of the mold. It therefore involves a study of pouring temperatures, mold temperatures, size of casting, and all other conditions affecting the rate of cooling.

(3) *Density of steel.* It is the usual thing for us to think of a casting as being either sound or porous; solid, or possessed of shrinkage cavities. These are things which we can see. However, it seems evident that the soundness of steel may run the gamut between apparent porosity down to a degree which may be indicated merely by a lack of density, and which can only be brought out by macroscopic or microscopic examination.

Practical Examples

For several years we have been heat-treating .50 to .60 carbon rollers, as shown in Fig. 1, to obtain a surface hardness of 400 to 450 Brinell. When cast in the form shown in (A), about 2 per cent cracked in the flanges during or after

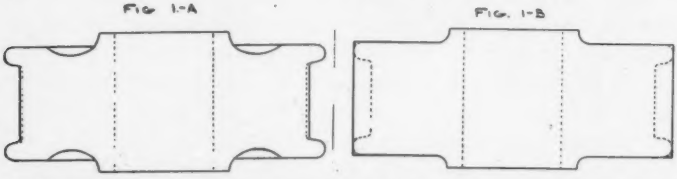

FIG. 1—ROLLER CASTING REDESIGNED TO PERMIT OF EASIER AND BETTER FOUNDRY PRACTICE. 1-B SHOWS PATTERN ALTERED

quenching, due to sand inclusions. The pattern was altered to the form shown in (B) to permit of easier and better foundry practice. Out of several thousand made to the new design, none have been lost in heat-treatment.

Fig. 2-A shows a nickel-chrome pinion weighing about 400 pounds. On account of the exacting nature of the service for which this pinion was intended, a sample was cut up after treatment. A slice was examined macroscopically and indicated lack of density at the root of the teeth. This conclusion was confirmed by the results shown in Table No. 1.

Table No. 1

	Yield Point Pounds	Ultimate Pounds	Elongation Per Cent	Red. of Area Per Cent
Test Bar	92,450	111,500	19.5	50.0
Flange	86,300	113,700	15.0	19.1
Root of Teeth	79,750	104,800	8.5	8.5

The part was redesigned, making the flange a separate unit. It was thus possible to get a more direct feed to the roots of the teeth. Heat-treated pinions of the new design, as shown in Fig. 2-B, have been in service for several years, and are reported to give excellent results.

Heat-Treating Practice

The treatment of castings, as has often been stated, is in every way similar to the treatment of other types of steel.

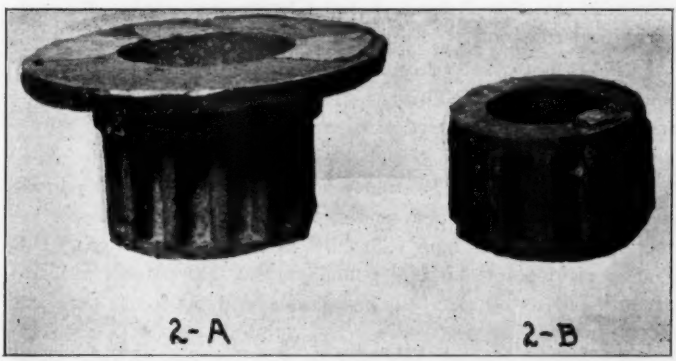

FIG. 2—PINION CASTING CHANGED IN DESIGN TO OBTAIN A DENSE METAL AT THE ROOT OF THE TEETH

Literature on this subject is so easily obtainable, and the art is so well standardized, that a detailed discussion is hardly necessary.

With proper furnaces and equipment, and careful heating, no trouble will be experienced from cracking and warp-

ing, unless on intricate pieces. While oil is probably the most satisfactory quenching medium for small work, water is more adaptable for large pieces, the water should be kept warm, at least 70 degrees Fahr. Several firms treating large quantities of castings, quench in water at 125 to 150 degrees Fahr., and the results are quite satisfactory. The castings should not be left in until cold, but for a definite period, usually determined by the point when the piece no longer kicks.

On removal from the water, the piece should be immediately drawn. Cracking is very likely to result on long standing. It has been rather definitely established that certain types of low-carbon alloy steels give better impact values if quenched from the draw, instead of cooling in the furnace. In such a case, a final heating at a still lower temperature is advisable in order to relieve all strain.

Physical Results on Nickel-Chrome Steel Castings

The steel about to be described is intended to develop wearing qualities as well as strength. It is a type frequently demanded by the Panama Canal Commission under the following specification:

Nickel 1.50-1.75 per cent; chromium, .60-.80 per cent; yield point, 55,000 pounds; ultimate strength, 95,000 pounds; elongation 12.5 per cent; reduction of area, 15.0 per cent.

This steel, in the annealed condition, will generally average about 60,000 pounds yield point or higher; 100,000 pounds ultimate strength; 15 per cent elongation; and 20 per cent reduction. Occasional bars will show as high as 70,000 to 75,000 pounds yield point, 110,000 pounds to 120,000 pounds ultimate strength, 20 to 30 per cent elongation, and 30 to 50 per cent reduction.

When heat treated, test bars of a .35 carbon nickel-chrome steel show the results given in Table 2.

As the carbon content increases, the added brittleness of the steel becomes quite noticeable, and the presence of even small amounts of impurities has a marked effect on the ductility. For this reason, results on different heats, or even on various bars from the same heat may not always be concordant.

Table No. 2

.35 Carbon, Nickel-Chromium Steel

Analysis—

Carbon	Mang.	Nickel	Chromium	Phos.	Sil.	Sul.
.35	.82	1.95	.66	.011	.36	.022

Treatment	Yield Pt. lbs.	Ultimate Strength lbs.	Elong. Per Cent	Reduction Per Cent	Brinell Hardness	Izod
Air cooled	75,000	104,750	21	48.3	..	..
*WQ 1500, D1150						
Fur. Cool from D...	92,650	105,800	23.5	52.0	248	37
Fur. Cool from D...	91,700	105,750	23.0	52.0	248	..
*WQ 1500, D 1150						
Quench from Draw...	89,000	107,000	21.0	51.1	255	44
Quench from Draw...	89,500	107,050	23.5	53.9	255	..

*WQ, Water Quench; D, draw

The following tables show results on .40 per cent and .45 per cent carbon nickel-chrome steel, respectively.

Table No. 3

Heat Treatment of .40 Carbon, Nickel-Chromium Steel

Anlysis—

Carbon	Mang.	Nickel	Chromium	Phos.	Sil.	Sul.
.40	.84	1.72	.63	0.11	.42	.032

Treatment	Yield Pt. lbs.	Ultimate Strength lbs.	Elong. Per Cent	Reduction Per Cent	Brinell Hardness	Izod
Air cooled, D 1150....	64,050	114,000	15	24	241	6
WQ 1500, D 1200.....	113,300	130,000	14.5	29.5	269	31
" "	79,300	109,300	16.0	37.9	..	..

Table No. 4

Heat Treatment of .45 Carbon, Nickel-Chromium Steel

Analysis—

Carbon	Mang.	Nickel	Chromium	Phos.	Sil.	Sul.
.46	.87	1.87	.83	.016	.44	.038

Treatment	Yield Pt. lbs.	Ultimate Strength lbs.	Elong. Per Cent	Reduction Per Cent	Brinell Hardness	Izod
Air cooled, D 1200..	68,500	109,450	19	27.8	241	6
WQ 1500, D 1200....	119,850	139,000	13.5	23.7	269	26
" "	106,700	120,250	17.5	35.7	..	..

The addition of about .4 per cent molybdenum to the above steel produces some interesting results. The general characteristics of such a steel, with .35 to .40 per cent carbon, are shown in table No. 5.

Table No. 5

Effect of Addition of .4 Per Cent Molybdenum

Treatment	Yield Pt. lbs.	Ultimate Strength lbs.	Elong. Per Cent	Reduction Per Cent	Brinell Hardness	Izod
Air Cooled 130,000		162,400	3.5	3.9	450	..
Furnace Cooled 104,000		140,400	13.0	24.4	302	6
Air Cooled, D 1250...	90,000	119,450	17.0	25.1	262	27
Furnace Cooled, D 1250	60,150	101,100	17.5	33.7	212	11

This steel is extremely sensitive to changes in the rate of cooling, and is not satisfactory for quenching. The upper critical point occurs at about 1350 degrees Fahr., but greater hardness can be obtained by heating to higher temperatures.

Our experience in the manufacture of alloy castings has been confined almost entirely to chrome-nickel steel. Over a period of many years, we have found this type most adaptable for our class of work. Many other types, such as plain chrome, chrome-vanadium, and chrome molybdenum, are now being employed in the manufacture of castings. The demand for these special steels is rapidly increasing, and it is well worth the founder's time to investigate the problems involved in their treatment.

Discussion—Heat Treatment of Alloy Steel Castings

Mr. Harsford.—I would like to know the carbon content and chrome and molybdenum nickel value in that molybdenum steel.

A. W. Lorenz.—The carbon content in every heat has been 0.37. We were aiming for 0.35 to 0.40. The chrome content is about 0.75. The nickel content is about 1.75. We figure that we could get better results for some classes of work by raising that nickel a little bit.

H. A. Neel.—I would like to ask Mr. Lorenz whether they do any machining on the castings in the rough before heat treatment, or whether they are heat treated before any machine work is done If you do the machining after heat treatment, how much difficulty do you encounter?

A. W. Lorenz.—That is an interesting question. Some of our castings, the most of them, we heat treat before machining, and with those particular castings we do not have any difficulty; in fact our machine operators prefer the heat-treated castings to the annealed, because they seem to be more uniform, they are tougher, but they really machine nicer from the standpoint of the machinist. Now our shop may be a little different from the average shop. We are used to hard steel. I remember not long ago we got some low-carbon steel, about 0.20 carbon. The op-

erator tried to machine it, and, of course, it turned out rough, so they immediately complained that it was too hard, and after quite a bit of argument we convinced them that it was really soft, but it machined about the same as our regular grade of annealed nickel-chrome steel. However, we have some castings which seem to be more difficult to machine. Those are gears about three feet in diameter, a sprocket gear. When we heat treat those, we do not get the whole thing in the water; we thought we would use our discretion and just put the teeth in the water. Our quenching tank is set right in the floor, and we have a rail on either side, so we run a bar through the hub of the gear, adjust the water level properly and roll them along, thereby quenching the teeth. It seems the machinists have difficulty on those, so now our practice is to machine the teeth first, then give the heat treatment, after which it goes back to the machine shop and the bore is machined out, as a general rule, though the heat-treated castings are no more difficult to machine than the annealed castings. We try to keep our brinell hardness almost the same as in annealed steel. We draw back practically in all cases to about 1200 degrees. We have some cases of gears with pinions with clutches in which we quench the clutches and do not draw them back as much, but ordinarily we draw them back to 1200 degrees; the machinist finds difficulty sometimes in getting the surface off. After he gets the surface off, gets rid of the scale, it is a very easy proposition. Our manganese content generally runs 0.60 to 0.80, and many times higher than that. We have basic furnaces and the manganese is thrown right into the furnace 10 or 15 minutes before tapping, and the result is that the content can be controlled as closely as you could if you threw it in the ladle, in some other processes. We feel that it helps the steel considerably. In some cases the manganese content of these nickel-chrome steels runs up as high as 0.93 per cent, but with proper heat treatment that does no harm whatever.

R. A. Bull.—I think that Mr. Lorenz has contributed some very valuable data on the various physical properties

to be obtained from alloy and cast steel, and we are all very much indebted to him. I would just like to ask him if he has any explanation which is satisfactory to himself concerning the variation in the results, for instance, the yield point shown on Table III, carbon and nickel chrome? In one case there was a value of 113,300 pounds given, and underneath is a value of 79,300.

A. W. Lorenz.—I might say that there, too, we were experimenting with something, and just as in Table IV we were really experimenting with furnace cooling and water quenching after the draw, but since the bars got confused, I made no mention of it in the paper; and also there was quite an element of doubt as to whether the pieces were quenched for the same length of time. I merely gave you the results to show you a minimum and a maximum. In Table No. II the conditions were taken care of by keeping our 18-inch bars in one piece, whereby the conditions were the same and the quenching was the same, and we knew our conditions were all right; therefore, I gave you the results with water cooling and quenching.

J. J. Bever.—I would like to ask Mr. Lorenz the highest carbon he has used in connection with molybdenum.

A. W. Lorenz.—We have only used one carbon, the 37 carbon. We made some experimental heats two years ago, and now we are starting in regular production, and all our heats have been around 37 carbon. In nickel-chrome steel we run as high as 80 carbon; it makes a harder casting, low ductility.

R. A. Bull.—Some people have found a rather unstable condition, I understand, in the use of molybdenum in varying quantities. I wonder whether Mr. Lorenz has found that to be true?

A. W. Lorenz.—I think that that is due to the very great degree of sensitiveness which molybdenum has on steel. A slight variation in the rate of cooling will give you wonderfully different results. The rate of cooling in

many of these tests was about three and a half hours from the annealing temperature down to 900 degrees which is about the rate which would be followed in our heat-treating furnace. When we give that treatment, we give it in our heat-treating shop, which has two small furnaces, and the rate of cooling is more rapid, but you have got to control your rate of cooling very carefully if you want to get uniform results. It is very sensitive. We experimented with some bars; we cooled them down to about 1100 degrees and then took a period of 18 hours between 1100 and 900, held them at that temperature for 18 hours and then cooled them slowly down from that temperature at the rate of the furnace and brought the elastic limit down to 4800 pounds. The ductility did not increase very much; so you see what you can do on slow cooling.

H. A. Neel.—I would like to ask Mr. Lorenz how he explains the decrease in yield point and ultimate strength on reheating a casting which has already been furnace cooled? What is the explanation of that from a structural standpoint?

A. W. Lorenz.—Well, in the case of the molybdenum steel, I think you have a carbide formation there, and it is probably the coalescence of the carbide particles which gives you the difference in your results, and it is so sensitive to hardening that even slow cooling will give you the same hardness as another steel would that got rapid cooling, but think that it is the carbide formation which coalesces and gives you your softer steel.

Mr. Powell.—I would like to ask what advantage is found from putting manganese in the furnace? Whether you found any bad effects from putting it in the ladle?

A. W. Lorenz.—This much is sure; you get it uniform throughout the bath; you do not have any trouble with hard spots, and also I do not think there is any doubt but what it improves the metal to a certain extent. Your metal is laying there in the furnace and undergoing a certain refining treatment due to the presence of the manganese.

A. W. Gregg.—We did a great deal of experimenting with that at the time we started the open-hearth furnace, and we did add manganese in the ladle and have the trouble Mr. Lorenz speaks of, hard spots and nonuniformity of the manganese through the steel, which was shown by taking test bars during the pour, taking as high as a dozen bars, and while it is rather extravagant we feel that it is very beneficial to the steel to give it in the case of nickel-chrome heats. Manganese was put in and for 15 minutes the steel was under a deoxidizing condition.

Heat Treatment of Steel Castings

By H. A. NEEL, Detroit, Michigan

The data presented in this paper were accumulated in the course of an investigation undertaken by the writer at the request of the Electric Steel Founders' Research Group. It was felt that the published information on annealing steel castings was of a very general character and that it was desirable to determine specifically the proper thermal treatment to apply to electric steel castings of carbon content from .20 to .32 which constitute the bulk of the Group's output.

In an investigation where the results are to be immediately applied practically, it would seem preferable to do the research work under the same conditions which will be encountered in plant practice. It is obvious, however, that by reason of the expense involved, it is desirable to conduct a preliminary elimination trial under laboratory conditions. That course was pursued, but care was exercised to make the laboratory conditions such that the final results could be checked by actual large annealing oven practice, and applied thereto.

Preliminary Tests of Laboratory Type

The laboratory apparatus used consisted of a Hoskins muffle type resistance electric oven, an Olsen tensile testing machine, a Charpy impact machine, and an Upton Lewis fatigue testing machine. All of the above are standard types and need no description. All temperature readings were taken with a Hoskins low resistance thermo couple and a Hoskins type P. R. recording pyrometer registering up to and including 2000 Fahr., both calibrated at the Hoskins plant just previous to the test. After the results on the first 20 bars had been studied it was decided to eliminate the fatigue tests and rely on the tensile and impact tests.

To make the results exactly comparable all the test bars used were cast from a standard pattern, molded in dry sand

and poured from the same heat. The standard test block is shown in Fig. 1. Its dimensions are, length 6 inches, width 7 inches, height over all 5 inches, depth of rib 1¾ inches, width of rib bottom 1¼ inches, top 1⅜ inches. This is the same type of test block used on both army and navy work in the plant with which the writer is connected. All the blocks for the test were molded in open sand and poured from hand shanks.

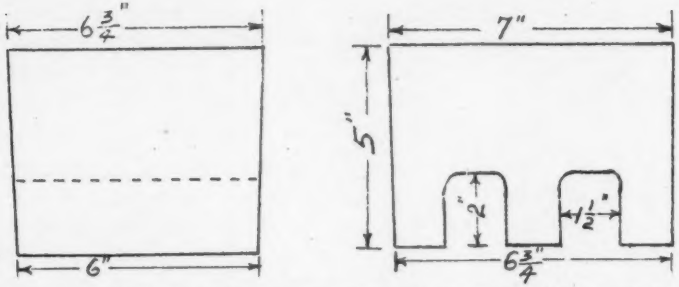

FIG. 1—STANDARD TEST BLOCK USED IN HEAT TREATING TESTS

The heat from which the test blocks were poured was a standard acid electric heat worked according to the usual practice at the plant of the Michigan Steel Casting Company. The charge consisted of 1700 pounds of foundry heads and gates and 4350 pounds of new plate scrap. Additions made in the furnace were 100 pounds of spiegeleisen, 55 pounds of 80 per cent ferromanganese and 20 pounds of 50 per cent ferrosilicon. Twenty pounds of coal were used as a deoxidizer on the slag one half hour previous to tapping, and the heat was finished under an apple green slag. No aluminum was added to the large ladle but one-half ounce per hundred pounds of steel was added in the hand shanks. The final analysis was carbon 0.27, manganese 0.78, silicon 0.31, sulphur .045, phosphorus .035 per cent.

The test blocks were lightly covered with sand immediately after being cast, and allowed to cool in the molds. They were shaken out, sand blasted, and the coupons removed with a band

hack saw. The three coupons from each block were stamped with the same serial number. The duplicate tensile test specimens and the impact and fatigue specimens bearing one serial number represent therefore bars from one test block given one specific treatment.

The sawed coupons were one inch thick. In actual practice we would consider it feasible to bring a casting 1 inch in thickness up to annealing temperature in 3 hours. We therefore adopted a standard time of 3 hours for raising from room temperature to 1650 degrees Fahr. Experiments showed that our small oven cooled so rapidly that to approximate conditions where an annealing charge is oven cooled, it would be necessary to retard the speed at which the small oven temperature was allowed to drop. Bars designated as oven cooled have been cooled from annealing temperature to 1200 degrees Fahr. at a rate of 150 degrees Fahr. per hour; from 1200 to 800 degrees Fahr. at a rate of 400 degrees Fahr. per hour; from 800 to 600 degrees Fahr. at a rate of 200 degrees Fahr. per hour; from 600 to 450 degrees Fahr. at a rate of 150 degrees Fahr. per hour; and from 450 degrees Fahr. to room temperature at a rate of 100 degrees Fahr. per hour. This corresponds to a cooling time of 10 hours in large oven practice.

Essential Factors in Heat-Treating

The three essential factors in the heat-treatment of cast steel are the soaking time, soaking temperature, and method of cooling. By holding two of these factors constant, the effect of variations in the third can be traced.

Method of Cooling to Obtain Best Properties

The first series of tests was for the purpose of determining the method of cooling which would impart the best properties to the test bars. For this series the time of raising to temperature was standard, 3 hours from room temperature to 1650 degrees Fahr.; the time at soaking temperature was standard, 3 hours, and three standard soaking temperatures were used, 1550, 1650 and 1750 degrees Fahr. For each standard soaking temperature one pair of bars was cooled in the oven;

one pair was cooled in the oven to 1300 degrees Fahr., and then in air; one pair was cooled in the oven to 1000 degrees Fahr. and then in air; and one pair was withdrawn from the oven at full heat and cooled at an unrestricted speed in air.

Table I

Table of Physical Properties, Uniform Soaking Period

Test No.	Cooling Method	Soaking Time Hours	Temp. Degrees F.	Yield Point Pounds per Sq. In.	Tensile Strength Pounds per Sq. In.	Per Cent Elong. In 2 Inches	Per Cent Reduction of Area	Impact Foot Lbs.
1	In oven	3	1550	37425	70250	25.0	31.8	17
				37300	70050	21.5	29.8	
2	In oven	3	1650	38750	72125	26.5	34.1	
				39250	72200	28.1	36.6	19
3	In oven	3	1750	37500	70250	23.4	29.8	15
				37125	70500	23.4	29.2	
4	Air cooled from 1300-D	3	1550	43500	74875	20.3	23.8	20
				43625	75750	20.3	22.7	
5	Air cooled from 1300-D	3	1650	44875	75250	20.3	22.7	
				43125	74450	20.3	24.8	23
6	Air cooled from 1300-D	3	1750	42150	76875	15.6	20.6	17
				Test piece too small for grips.				
7	Air cooled from 1000-D	3	1550	39375	71850	32.8	41.9	
				37875	71550	31.2	42.2	18
8	Air cooled from 1000-D	3	1650	39060	71875	26.5	32.5	
				40250	71750	29.7	33.4	20
9	Air cooled from 1000-D	3	1750	38500	71750	23.4	26.5	
				39375	72000	23.4	29.2	15
10	Straight air cool	3	1550	44750	74375	21.9	24.1	
				44100	74900	20.3	21.6	21
11	Straight air cool	3	1650	44750	77250	26.5	34.4	
				43500	76250	28.1	37.3	29.5
12	Straight air cool	3	1750	42000	76125	26.5	32.8	
				41050	75250	23.4	30.8	30.0

Results on this series are given in Table No. 1. After a careful consideration of these results we decided that the best temperature for a 3-hour soaking period is 1650 degrees

Fahr. Bar No. 7 annealed at 1550 degrees Fahr., oven cooled to 1000 degrees Fahr. and air cooled from there down has the highest ductility of the series but its impact value is low and it falls much below bar 11 in yield point, and ultimate strength. We further concluded that the best method of cooling is freely in air. Withdrawing castings from the oven at 1000 degrees Fahr. has no serious effect on ductility, but does effect impact value. Withdrawal at 1300 degrees Fahr. apparently vitiates the heat-treatment.

The Soaking Period

Having standardized on air cooling, the next step was to determine the effect of a soaking period less than three hours,

Table II

Table of Physical Properties

Test No.	Cooling Method	Soaking Time Hours	Temp. Degrees F.	Yield Point Pounds per Sq. In.	Tensile Strength Pounds per Sq. In.	Per Cent Elong. In 2 Inches	Per Cent Reduction of Area	Impact Foot Lbs.
13	Air cool	2	1550	40500	76875	23.4	32.5	23.3
	Air cool			41250	75625	21.5	27.8	
14	Air cool	2	1650	44000	76500	23.4	30.8	25.1
				43950	76075	25.0	33.1	
15	Air cool	2	1750	41300	76200	20.3	25.2	23.5
				41875	75300	18.7	25.2	
16	Air cool	1	1550	44175	77000	21.5	27.5	23.5
				43200	76600	23.4	33.4	
17	Air cool	1	1650	45375	76550	20.3	26.1	19.5
				44875	75925	21.5	26.8	
18	Air cool	1	1750	43575	77000	26.5	39.1	28.5
				43250	77125	26.5	41.0	
19	Air cool	½	1550	40625	75875	18.7	27.8	20.5
				40250	76250	18.7	26.5	
20	Air cool	½	1650	46100	75175	23.4	28.5	21.5
				45375	74750	20.3	25.8	
21	Air cool	½	1750	43375	77400	26.5	39.1	25.0
				44000	77500	25.0	36.0	
22	Air cool	½	1850	41500	76875	26.5	39.1	28.5
				40750	76875	24.5	34.1	

and the possibility of obtaining equally good results by a shorter anneal at a higher temperature. For this series the time of raising was standard, the time being 3 hours; the method of cooling, freely in air, was standard; and 3 standard soaking temperatures, 1550 degrees Fahr., 1650 degrees Fahr., and 1750 degrees Fahr. were employed. The variable was the length of time the bars were held at maximum temperature.

A study of Table 2 in comparison with Table 1, shows that, as the length of time during which the bars were soaked decreased, a higher soaking temperature became necessary to produce results. Compare bars 14, 17 and 20 with bar 2 of Table 1 and observe the decrease in ductility and impact figures, indicating the desirability of maintaining a 3-hour soaking period for a temperature of 1650 degrees Fahr. Then compare bar 12, Table 1, with bars 15, 18, 21 and 22, Table 2, and observe that the process of heat-treating is as well accomplished by soaking for a shorter period at a higher temperature. None of the bars heated at 1750 degrees Fahr. exhibit superior qualities as compared to those heated at 1650 degrees until the soaking period is decreased to 1 hour.

The Effect of a Secondary Heating on Air Cooled Bars

The third step was to ascertain the effect of a secondary heating on the air cooled test bars. The first series of bars in this section was discarded because of faulty temperature control and it was necessary to use bars from a different heat, which, however, checked very closely in analysis and tensile properties, with the original heat. The analyses were:

Original heat—C .27, Mn .78, Si .31
Substitute heat—C .28, Mn .72, Si .35

The tensile properties on bars soaked for one hour at 1750 degrees Fahr. and air cooled were:

	Yield Point Lbs. per Sq. Inch	Tensile Strength Lbs. per Sq. Inch	Elongation	Per Cent Reduction Area
Original Heat	43,575	77,000	26.5	39.1
Original Heat.....	43,250	77,125	26.5	41.0
Substitute Heat.....	40,375	75,425	29.5	40.1
Substitute Heat.....	39,800	75,300	29.5	41.9

All the bars in this series were soaked at 1750 degrees

Fahr. for 1 hour, cooled freely in air, and redrawn to the temperatures given. Maximum ductility was obtained on the bars drawn at 1250 degrees Fahr. Above this temperature, as the drawing temperature approached the lower critical point, the ductility decreased.

Table III

Record of Physical Tests of 2nd Air Cool and Draw Series

Bar No.	Treatment Degrees Fahr.	Yield Point Pounds	Tensile Strength Pounds per Square inch	Per Cent Elongation	Per Cent Reduction of area	Remarks Fracture
23	As cast.....	34750	70250	19.5	27.2	Crystal Puckered.
	As cast.....	35500	70500	21.5	27.2	Crystal Puckered.
24	A. C. No. Draw..	40375	75425	29.5	37.3	Semi Cup Silky.
	A. C. No Draw...	39800	75300	29.5	40.1	Semi Cup Silky.
25	A. C. 1000.....	40875	74750	29.0	41.9	Semi Cup slight flaw.
	A. C. 1000.....	40750	74800	29.0	50.0	Semi Cup Silky.
26	A. C. 1050.....	39750	74800	30.5	50.0	Semi Cup Silky.
	A. C. 1050.....	39800	73875	30.0	50.0	Semi Cup Silky.
27	A. C. 1100.....	39500	73700	29.5	47.2	Semi Cup slight flaw.
	A. C. 1100.....	39775	73300	30.5	49.5	Semi Cup Silky.
28	A. C. 1150.....	38250	70550	21.0	30.1	Semi Cup Flaw.
	A. C. 1150.....	37900	71500	33.5	49.8	Semi Cup Silky.
29	A. C. 1200.....	36875	69000	33.0	56.5	Cup Silky.
	A. C. 1200.....	36875	69125	31.0	49.5	Semi Cup Silky.
30	A. C. 1250.....	37100	68000	32.5	53.3	Semi Cup Silky.
	A. C. 1250.....	36750	68400	35.1	58.1	Semi Cup Silky.
31	A. C. 1300.....	38500	72375	30.0	47.8	Semi Cup Silky.
32	A. C. 1350.....	39250	73750	29.5	45.1	Semi Cup Silky.
	A. C. 1350.....	39250	73950	28.5	44.8	Semi Cup Silky.

Note—A. C. means air cooled. Temperatures given are drawing temperatures.

No drawing temperatures below 1000 degrees Fahr. were considered because the discarded set of bars had shown no beneficial results at temperatures below that point.

The fourth section was devoted to ascertaining the effect of oil and water quenching on bars from the standard heat after soaking for 1 hour at 1750 degrees Fahr. Bars were redrawn to the temperatures indicated.

The water quenched bars are slightly superior to those quenched in oil and drawn at the same temperature. It is interesting to compare the water quenched bar drawn at 1200 degrees Fahr., No. 36 with the air cooled bar No. 29 in Table 3 which was drawn at the same temperature.

Table IV

Oil and Water Quenched Bars

Bar No.	Soaking Temp. Degrees Fahr.	Time Hours	Quenching Medium	Drawing Temp. Degrees Fahr.	Drawing Time Hours	Yield Point Pounds per square inch	Tensile Strength Pounds per square inch	Per Cent Elongation	Per Cent Reduction of Area	Impact	Fracture		
33	1750	1	Water	600	2	68750	107750	10.5	16.6	..	Irregular		
33	1750	1	Water	600	2	66250	99500	14.0	23.3	..	Irregular		
34	1750	1	Water	800	2	65500	99550	14.5	26.5	17	Irregular		
34	1750	1	Water	800	2	68500	101125	14.5	25.2	..	Irregular		
35	1750	1	Water	1000	2	59250	93125	16.5	30.1	22	Irregular		
35	1750	1	Water	1000	2	58950	92625	16.5	32.5	..	Irregular		
36	1750	1	Water	1200	2	52250	82175	17.5	31.5	25	Irregular		
36	1750	1	Water	1200	2	50750	81250	17.5	30.8	..	Irregular		
37	1750	1	Oil	600	2	66750	99500	11.0	18.9	22.5	Irregular	and Coarse	Granulated
37	1750	1	Oil	600	2	66000	98000	11.5	18.9	..	Irregular	and Coarse	Granulated
38	1750	1	Oil	800	2	64000	90125	11.5	19.9	..	Irregular	and Coarse	Granulated
38	1750	1	Oil	800	2	65500	92550	11.5	22.4	..	Irregular	and Coarse	Granulated
39	1750	1	Oil	1000	2	59375	97050	14.5	25.5	25	Irregular	and Coarse	Granulated
39	1750	1	Oil	1000	2	56750	87000	16.0	26.5	..	Irregular	and Coarse	Granulated
40	1750	1	Oil	1200	2	54875	85875	17.0	29.8	21	Irregular		
40	1750	1	Oil	1200	2	53750	82750	15.5	29.2	..	Irregular		

	Yield Point	Tensile Strength	Elongation	Per Cent Reduction of Area
No. 36	52,250	82,175	17.5	31.5
No. 36	50,750	81,250	17.5	30.8
No. 29	36,875	69,000	33.0	56.5
No. 29	36,875	69,125	31.0	49.5

The relative merits of the two methods of treatment are plainly shown.

Check Tests

All the work up to this point was done in the laboratory. From the results obtained certain theories had been formed regarding desirable heat-treating practice in large oven operation. To verify these theories 24 test blocks were cast on 24 successive heats. The test bars were removed from the blocks and two bars from each heat were sent to the Lebanon Steel Foundry for heat treatment, while the third bar was heat-treated in our own plant. The idea in making the division was to check results from two different systems of treatment. At Lebanon all the bars were soaked for three hours at 1650 degrees Fahr. and oven cooled. In our own plant one bar was placed on each charge for 24 successive heat treating charges. The ovens used at both plants were car type ovens, oil fired, with over-head burners.

At the plant of the Michigan Steel Casting Company, the cars were lightly loaded. Temperature readings were taken with couples on the bottom of the charge so that the pyrometer did not register full heat until the whole charge was heated throughout. The time of holding was taken from the time the charge was heated throughout until the car was withdrawn from the oven at full heat. Section of the castings under treatment ranged from ¼ to 2 inches. The charges consisting of heavier castings are the ones held longer. The bars were placed about one-third of the way down in the charge. Temperature at the location of the bars was from 1700 to 1725 degrees Fahr. Results of the series are given in Table 5. M indicates bars treated and pulled at Detroit, L, those treated and pulled at Lebanon.

It will be noted that on a majority of the bars, the air cooling treatment from a temperature in excess of 1700 de-

Table V

24 Bars Annealed in Oil Fired Oven. Chemical and Tensile Properties

No.	C.	Mn.	Si.	Yield Point Pounds per square inch	Tensile Strength Pounds per square inch	Per Cent Elongation	Per Cent Reduction of Area	Fracture	Soaking Time Hours
1 L				33500	63500	39.0	58.0		3
1 L				33750	63500	39.0	55.0		3
1 M	.19	.73	.35	35750	66750	36.0	58.4	Silk Silky Cup	1½
2 L				32250	63200	39.0	55.0		3
2 L				33250	63550	37.5	54.5	Porous ends.	
2 M	.19	.75	.30	38575	66750	37.5	60.6	Silky Cup.	1
3 L				32750	64750	36.5	52.0		3
3 L				32500	64750	37.5	52.0		3
3 M	.20	.74	.26	36500	67725	35.0	54.9	Silky ½ Cup.	2
4 L				33000	68250	34.0	47.0		3
4 L				33500	68000	37.0	47.0		3
4 M	.24	.80	.33	40000	72875	35.0	55.5	Silky Cup.	1
5 L				38250	74250	29.0	39.0		3
5 L				39000	75000	28.0	39.0		3
5 M	.33	.76	.37	40250	78675	29.5	46.9	Silky ½ Cup.	1½
6 L				38500	72250	32.0	43.5		3
6 L				39000	72500	33.0	42.5		3
6 M	.27	.71	.34	39125	76575	31.0	48.6	Silky Cup.	1
7 L				34000	66500	37.5	46.0		3
7 L				Spoiled in turning					3
7 M	.24	.72	.34	38750	68500	35.5	56.8	Silky Cup.	1½
8 L				38250	71500	30.0	44.0		3
8 L				38750	73000	30.0	44.0		3
8 M	.26	.83	.43	42625	77400	31.0	45.1	Silky ½ Cup.	1
9 L				32500	70500	33.0	45.0		3
9 L				31500	71000	33.0	46.0		3
9 M	.23	.77	.34	36875	75375	29.0	40.4	Silky Cup.	1
10 L				36750	71500	32.5	43.5		3
10 L				36250	71000	32.5	45.0		3
10 M	.27	.86	.42	Defective.					1½
11 L				36000	69250	33.0	47.5		3
11 L				35000	68000	33.0	47.5		3
11 M	.22	.77	.31	37750	70500	34.5	55.2	Silky Cup.	1½
12 L				36000	71500	32.5	45.0		3
12 L				36500	71000	32.5	45.0		3
M12	.27	.77	.42	42000	76575	33.5	55.2	Silky Cup.	1

Table V (continued)

24 Bars Annealed in Oil Fired Oven. Chemical and Tensile Properties

No.	C.	Mn.	Si.	Yield Point Pounds per square inch	Tensile Strength Pounds per square inch	Per Cent Elongation	Per Cent Reduction of Area	Fracture	Soaking Tims Houre
13 L				37500	71000	32.5	47.0		3
13 L				Spoiled in turning.					3
13 M	.26	.84	.39	39275	74125	31.5	52.5	Silky Cup.	½
14 L				37500	78500	30.0	37.0		3
14 L				37000	78500	30.0	35.5		3
14 M	.32	.80	.38	45250	85050	25.0	40.7	Silky lateral	1
15 L				34000	65500	36.5	52.0		3
15 L				34000	65500	36.5	51.0		3
15 M	.19	.78	.31	39250	67875	35.5	54.7	Silky Cup.	1½
16 L				36000	69000	32.5	45.0		3
16 L				Spoiled in turning.					3
16 M	.26	.71	.34	39250	71750	34.5	50.3	Silky Cup.	1
17 L				35500	71000	32.5	45.0		3
17 L				35000	71000	32.0	45.0		3
17 M	.24	.80	.36	40500	75500	33.5	51.7	Silky Cup.	1
18 L				35500	72000	31.5	42.5		3
18 L				36000	72000	32.0	42.5		3
18 M	.26	.80	.35	40550	75575	31.0	49.2	Silky Cup.	1½
19 L				35500	71000	32.5	42.5		3
19 L				36500	71000	31.5	43.0		3
19 M	.30	.77	.39	44250	76000	31.5	43.1	Silky Cup.	2
20 L				40500	70500	28.0	44.0		3
20 L				33000	68750	32.0	45.0		3
20 M	.27	.72	.27	40775	73500	31.5	53.3	Silky Cup.	1
21 L				36000	72500	30.0	43.0		3
21 L				36500	73250	30.0	40.5		3
21 M	.29	.82	.40	43300	79000	31.5	52.0	Silky Cup.	2
22 L				33500	62000	37.5	53.5		3
22 L				33000	63000	39.5	54.0		3
22 M	.20	.71	.27	38625	66700	37.5	61.8	Silky Cup.	2
23 L				33000	62500	37.5	54.5		3
23 L				32250	62500	37.0	51.0		3
23 M	.16	.83	.38	36750	64250	36.5	56.0	Silky Cup.	2
24 L				32500	64250	37.5	51.0		3
24 L				32750	64250	36.0	50.0		3
24 M				Lost in process.					

grees Fahr. produced higher ductility values than oven cooling from 1650 degrees Fahr. in spite of the fact that the soaking time was much less and that no subsequent drawing treatment was resorted to. The analysis range of the bars was purposely made wide enough to show whether any modification of the method of heat-treatment should be made as the carbon increases. Within the range taken there was no marked decrease in ductility in the higher carbon bars, but it is felt that above .30 carbon a too severe air quenching might necessitate a secondary heating to secure the desired ductility.

Conclusions

The heat-treating research is still being prosecuted and the problem now is to secure practical application of the information gained experimentally. Having determined the temperature and treatment which will give good commercial results, we, must study heat distribution within our ovens to make sure that all castings in a charge receive the same treatment. This implies that due care shall be taken in the location and protection of couples so that the temperatures shown on the recording meter will give a true picture of conditions in the castings of the heat-treatment charge.

We have drawn the following tentative conclusions from our work to date:

1. Where by reason of the mass of the individual castings or the size of the oven charge, it is necessary to hold the oven at maximum temperature for several hours to insure heat penetration, that temperature should be 1650 degrees Fahr.

2. Castings should either be cooled in the oven to 1000 degrees Fahr. or straight air cooled. No intermediate practice such as cooling to 1300 degrees Fahr. and then withdrawing from the oven, or opening the oven doors and allowing the castings to cool at an accelerated rate in the oven will give desirable physical properties.

3. A short soaking at a fairly high temperature will produce as good results as a longer soaking at a lower temperature, if sufficient time is allowed to insure heat penetration. For light uniform sections, one hour soaking at 1750 degrees

Fahr. with air cooling will yield maximum strength and adequate ductility.

4. High ductility can most surely be obtained by air quenching and reheating to a temperature between 1100 degrees Fahr. and 1250 degrees Fahr.

5. By employing oil or water quenching with a suitable draw, physical properties higher than ordinary can be obtained.

Standards for Routine Heat Treating

For the guidance of the operating men in the plants of the Electric Steel Founders' Research Group, definite standards have been established to cover all routine heat treatment. They are shown below to indicate the extent to which some producers of steel castings believe heat-treatment can be practically and wisely regulated in the light of present knowledge.

1. All castings except only such as are stipulated by the customer to be delivered to him in a raw or unannealed condition shall be heat-treated as prescribed in paragraphs 3 to 7 inclusive.

2. All castings repaired for cracks; all castings in grade A; and all other castings believed by the makers to be logical substitutions for malleable iron from the standpoint of strength shall be thoroughly heat-treated after welding even when this necessitates one or more supplementary heat-treatment operations. All castings in any grade shall be thoroughly heat-treated after each welding operation when welding has taken place on a surface to be machined, or on a surface believed by the maker to be relatively important under wear or stress.

4. The maximum temperature applied to all carbon steel castings not exceeding .30 per cent in carbon shall be no lower than 1600 degrees Fahr. (870 degrees Cent.) nor higher than 1650 degrees Fahr. (900 degrees Cent.) After the required maximum temperature has been applied for the proper time, all carbon steel castings shall either be cooled in the annealing oven to 1000 degrees Fahr. (540 degrees Cent.) or lower, before removal from the oven; or be permitted to cool in the air at room temperature, immediately after removal from the oven while the latter is subjected to the prescribed maxi-

mum temperature. The maximum limit of 1000 degrees Fahr. (540 degrees Cent.) permitted for the oven cooling of carbon steel castings shall be determined by pyrometer reading, or by the loss of all temporary reddish color resulting from heat.

3. The maximum temperature (between permissible ranges) employed in every heat-treatment which is intended to produce the desired results without a subsequent heat-treatment, shall be maintained continuously for at least two hours for all carbon steel and alloy steel castings of any composition.

5. For alloy steel castings and for carbon steel castings having a carbon content exceeding .30 per cent each group plant shall employ maximum temperatures and cooling operations which in the opinion of the said plant are most suitable for the chemical composition and design of the castings.

6. Every heat-treating operation shall be accompanied by the use of a recording pyrometer. All recording and indicating pyrometers shall be periodically calibrated and shall always be maintained in first class condition.

7. To supplement the use of pyrometers at least one fracture or bend test piece of appropriate dimensions shall be placed in every annealer-load subjected to heat-treatment. A sufficient number of such test pieces shall be placed in every annealing oven at least twice weekly. The purpose of these annealing test pieces is to determine by degrees of bend or by nature of fracture or both, the suitability of the temperature actually applied to all castings whatever be their location or partially insulated condition in the annealing oven as compared with the pyrometer couples.

The writer wishes to acknowledge the assistance of his associates in the Research Group to which reference has been made, in the prosecution of the investigation here reported.

Discussion—Heat Treating of Steel Castings

Mr. Uhler.—I would like to ask Mr. Neel what detrimental effects he found in the use of the higher temperatures in the way of grain growth, and also how he came to the conclusion that three hours was the proper soaking time?

H. A. Neel.—We found that the results obtained were a direct function of time and temperature. In other words, we encountered no detrimental effects from the higher temperatures unless they were continued over too long a time. For instance, we have one bar at 1850 degrees for half an hour which gives very desirable properties. At the same time if we maintained a temperature of 1950 degrees for three hours, we would have found a decided decrease in ductility and also in strength. In other words, we would have encountered a grain growth which would have detrimentally affected the properties of the bar.

Mr. Uhler.—The reason I asked the question is that I have to deal with castings that run from a quarter of an inch up to 20 inches in thickness and three hours' soaking does not seem just right.

H. A. Neel.—I prefaced the paper by saying that the class of castings we deal with run ordinarily a quarter of an inch to two inches in thickness. We would certainly consider it necessary in annealing castings 20 inches in thickness to have maintained that annealing temperature for, say, seven or eight hours. In other words, we have established the three-hour limit as applying to our particular class of castings. Occasionally we do run heavy castings, die blocks or something of the kind and we apply more or less the old rule of thumb, one hour of soaking per inch of thickness.

Mr. Uhler.—I ran a great many experiments on the subject of soaking. I found that soaking temperatures, as used in forge shops throughout the country, were ¾ of an hour to the inch, up to an hour and a half to the inch, which gave results more comparable than any other.

R. A. Bull.—I think that the question of time in connection with the soaking of castings is one that has not been very thoroughly clarified in the literature on the subject of heat treatment or annealing castings. I know of at least a few concerns which employ from six to nine days in the ordinary heat treatment of castings as high as 36 inches thick. I think that a good deal of light can easily be thrown on that subject. Mr. Neel has pointed out that his investigation relates to castings with a very thin section; no conclusion is drawn and nothing is attempted to be advocated as to heavier sections than those mentioned in the paper.

J. F. Harper.—I would like to ask Mr. Neel if he has any data available on the difference of the distortion due to the various heat treatments, and also if, due to these various heat treatments in subsequent machines, certain stresses were relieved, causing the distortion?

H. A. Neel.—Do I understand, Mr. Harper, that you are afraid that in a cooling treatment you will encounter more warping than in oven cooling on the same casting?

J. F. Harper.—With certain temperatures, I am afraid of that. I wonder if 1650 or 1750 air cooled would prevent that? One of them must be correct.

H. A. Neel.—I would say that we have found no difference in the warpage of our castings when air cooled as compared with oven cooled, we make a good many intricate section castings and we find it necessary to put a straightening operation on the more intricate of those castings regardless of whether they are oven cooled or air cooled.

R. J. Doty.—I would like to answer Mr. Harper's question from a practical standpoint, that we have been

using those particular temperatures for more than a year and the customers do not complain of any distortion in the casting either before or after machining.

A. W. Lorenz.—I would like to say that once in a while in our plant, not lately, but some time ago, we did encounter distortion after machining and there must have been something in the annealing; at that time we were not engaged in heat treating; these were very large pieces, but those pieces, which were rack segments were put on the machine and the first cut was taken, and that first cut released the strain in the casting so that after that rack segment opened up it was no longer the correct radius.

H. A. Neel.—I would like to say that the value of this paper, as we see it, is not in laying down any rules for your heat treatment; it is rather in pointing out the way we approach the problem of establishing those rules for our own particular class of castings. No attempt was made to lay down blanket rules for the other plants' heat treatment, but we do believe that these rules are thoroughly applicable to our own plants' heat treatment.

Mr. Hovey.—The most interesting part of your paper to me particularly is your statement that withdrawal at 1300 degrees Fahr. apparently vitiates the entire heat treatment. I cannot quite reconcile that with No. 4 of the standards on page 206 in which you say that after the required maximum temperature has been applied for the proper time, all carbon steel castings should either be cooled in the annealing oven to 1000 degrees Fahr. or lower before being removed from the oven, or be permitted to cool in the air at room temperature. Perhaps that is perfectly plain to others, but it seems to me there is a conflict there.

H. A. Neel.—"Or be permitted to cool in the air at room temperature immediately after removal from the oven while the latter is subjected to the prescribed maximum temperature." We are using a car type of oven, and the carriage is withdrawn from the oven at 1750 degrees. In other words, it is what is commonly described as a straight air cooling. We find that if we attempt to econ-

omize between those two temperatures by such expedients as allowing the carriage to remain in the oven until it has passed the theoretical lower limit of the critical range and then immediately withdrawing it, or by allowing it to remain in the oven and opening the oven doors to expedite the cooling, we do not get desirable physical results.

Discussion—Heat Treatment of Steel Castings

By JOHN HOWE HALL, High Bridge, N. J.

Mr. Neel and the Electric Steel Founders' Research group are to be congratulated on this paper which presents most useful and valuable information in an excellent manner.

Apparently in heating up the air-cooled and quenched bars for a "draw" the specimens were not held at the drawing temperature for a period of time; at least no time is mentioned so that it is a fair inference that but a short time was used. In the case of the bars cooled in air a short draw is sufficient to give excellent ductility to the comparatively soft steel used for the experiments. I believe, however, that if the drawing temperature were held for several hours that better toughness would be secured even in the air-cooled bars, and that in the oil and water quenched bars the improvement in ductility would be very marked. In my own experience, I have found that the drawing temperature should be maintained for several hours in the case of most steels after air cooling and in the case of all steels after oil or water quenching. This is especially important in the case of steel which has been quenched in water or oil as a short draw is insufficient to remove to the requisite degrees the hardening effect due to the oil or water quenching.

In our own practice, we find that steel, oil or water quenched, and given a proper draw is as tough or tougher than the steel air cooled and reheated, and at the same time has both a higher yield point and a higher tensile strength. The table on page 210 indicates that the water quenched bars are much inferior in toughness to those air cooled and reheated and, as this is not the case when oil quenching and reheating are more carefully carried out, it is rather unfortunate in so excellent a paper to give the impression that oil or water quenching is undesirable from the point of view of the physical properties obtained.

It is particularly gratifying to me to see the interest being taken during the last few years in the heat treatment of steel castings, in which I have long been greatly interested, and especially to see the work being taken up with such care by the Electric Steel Founders' Research group whose reports are rapidly coming to be recognized as authoritative.

Report of A. F. A. Representative on Joint Committee on Investigation of Phosphorus and Sulphur in Steel

Your representative on the joint committee on investigation of phosphorus and sulphur in steel hereby reports no definite action since our last convention, by the joint committee, which permits an announcement at this time, comparable with that made at the Rochester convention.

Since the last meeting of the American Foundrymen's association, the subcommittee on tests of the joint committee has done a great deal of work in testing, following activities of the subcommittee on manufacture. This work is being prosecuted as vigorously as possible, with extreme care.

Your representative hopes consideration of the entire personnel of the joint committee can be given data accumulated by its subcommittee on tests at a reasonably early date, to permit publication to the members of the American Foundrymen's association of important facts under investigation in the cooperative and comprehensive way characterizing the make-up and procedure of the joint committee.

R. A. Bull,

American Foundrymen's association representative on joint committee on investigation of phosphorus and sulphur in steel.

Production of Steel Track Links and Grousers for Army Tractors

By H. C. MINTON, Watertown, Mass.

During the past two years the foundry at Watertown arsenal has been called upon to manufacture several thousand track links and grousers for the different models of army tractors. The link for the ten-ton tractor and the grouser for the five-ton tractor have been taken as typical and a brief description of the methods employed in their production follows.

Molding

The grouser, shown in Fig. 1, was made on a plain jarr machine, two in a flask of suitable size, with a metal pattern mounted on a metal plate. Both halves of the grouser flask were sufficiently light so that they were easily rolled over by hand by one man. A comparatively small number of these castings were ordered on the initial procurement instructions and it was decided to use wooden flasks in order to get them out as expeditiously as possible. One hundred such flasks were made. They were reinforced crosswise and lengthwise with iron rods and a total of some eight thousand castings have been made in them with very few flask replacements. The original flasks are still in service and are apparently good for several thousand more castings. Machine or semi-skilled molders were used and a production of 199 castings per man per eight hour day was averaged. This included molding, setting cores, closing and clamping the mold ready for pouring.

The track link shown in Fig. 2 was also made in a wooden flask and for the same reason given above. The clean casting weight of the link was approximately forty-six pounds and the size of the flask made it rather difficult for the machine molder and helper to roll over. A special rigging was devised by the superintendent of our pattern shop which obviated the customary method of hand clamping. This device is shown in Fig. 3 and again in Fig. 7. Fig. 4 shows the pattern in position.

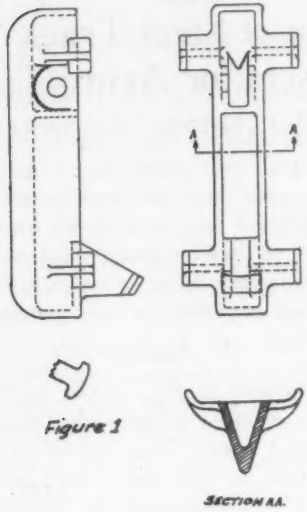

FIG. 1

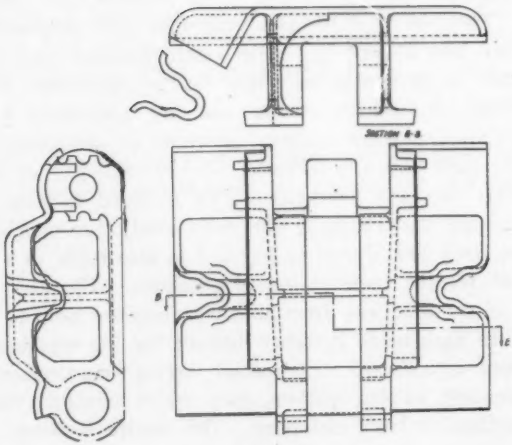

FIG. 2

Fig. 5 shows a sheet metal frame in position around the pattern and Fig. 6 the nowel section of the flask in position. Facing sand was shoveled in the sheet metal frame and the flask filled with heap sand. The bottomless sheet metal frame was then withdrawn and the mold jarred up. The bottom board was placed in position and the mold board, nowel and bottom board securely clamped by the device mentioned above. A pull on the chain hoist attached to a jib crane and the nowel was easily

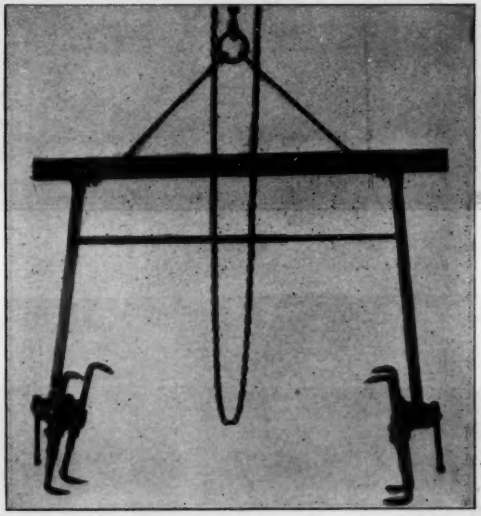

FIG. 3

rolled over. Figs. 7 and 8 show the flask ready to be rolled over and illustrate the functioning of the clamping device.

To avoid any hand finishing a stripping plate shown in Fig. 9 was used. Three dry sand cores were necessary with this pattern and are shown in position in Fig. 10. Fig. 10 also shows the perfectly flat cope with a small runner core that was found necessary to prevent cutting.

One machine molder and helper, after having been broken

FIG. 4

FIG. 5

FIG. 6

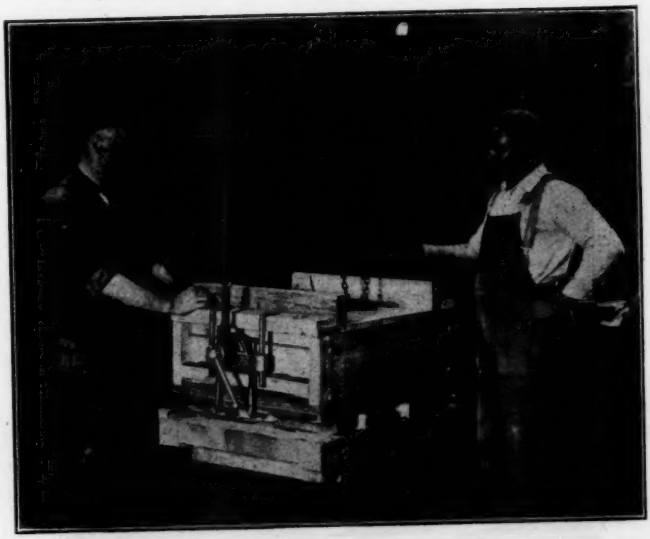

FIG. 7

FIG. 8

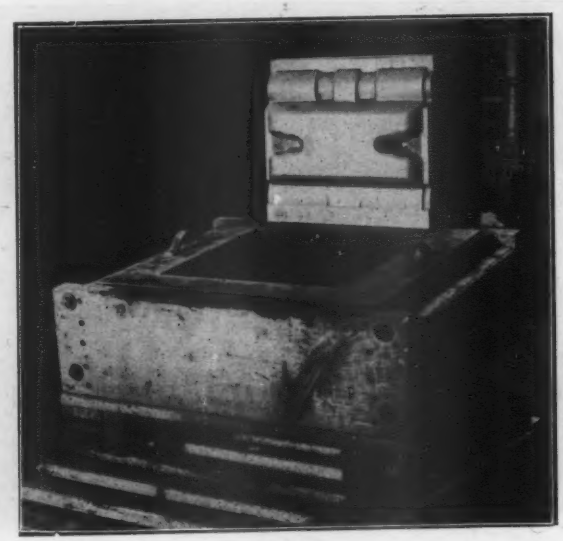

FIG. 9

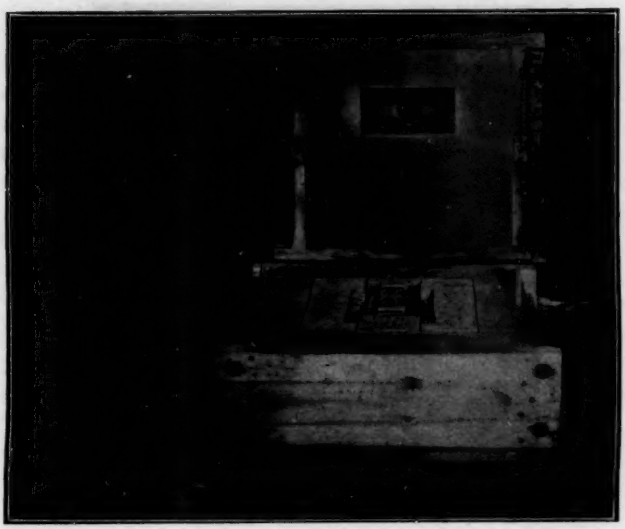

FIG. 10

in on the job, averaged fifty complete molds ready for pouring in an eight-hour day.

Alternate Method of Molding Link

The above described method of molding the track link necessitated the use of coremakers and drying ovens for the cores. This might prove awkward at times when the core-room was stocked with work. Accordingly the following method was adapted for use as occasion demanded.

In this method the mold was made complete by the machine molder, the three dry sand cores necessary in the method first described being replaced by a single green sand core. Fig. 11 shows the two halves of the core-box. The nowel section of the core-box was first rammed up and set to one side. The cope section of the core-box was then rammed up and closed on the nowel section. The entire core box was then rolled over and nowel section lifted. The nowel section of mold Fig. 12

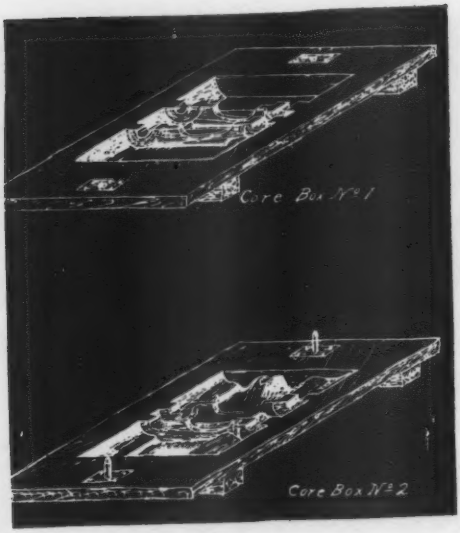

FIG. 11

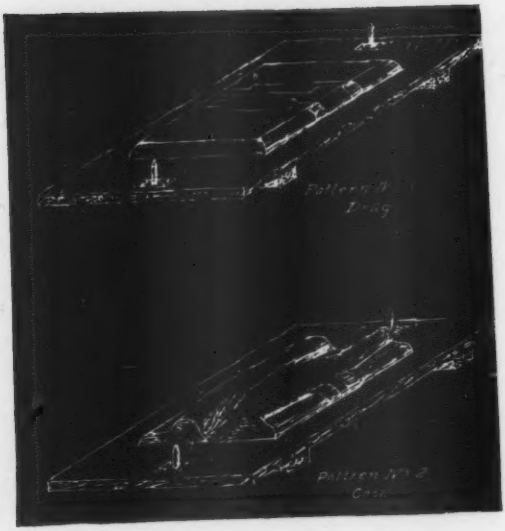

FIG. 12

was then jarred up and closed on the core-box. The flask was then clamped, rolled over and cope section of core-box lifted The cope section of mold was next jarred up and closed, thus completing the flask ready for pouring.

Making the mold in this manner did away with fifty per cent of the fins obtained with the first method described and thereby decreased the chipping and cleaning cost. Production was lower per machine but on the other hand the core-room and drying ovens were relieved of congestion. Based on the cost system in use the above method proved to be approximately fifteen per cent cheaper than the first method described.

Heat Treatment

Link castings were heated to 900 degrees Cent. for two hours and quenched in water for 15 seconds, drawn two hours at 700 degrees Cent. and furnace cooled.

Grouser castings were given identically the same treatment.

Chemical composition of five successive heats and physical properties obtained from coupon tests representing them are tabulated in Table 2.

Table 1

	Physical Specifications			
	Yield point pounds per square inch	Tensile strength pounds per square inch	Per cent elongation in 2 inches	Per cent contraction of area
Link	36,000	80,000	15	20
Grouser	27,000	60,000	22	30

	Chemical Specifications				
	C	Mn	Si	P	S
Link	35/45	50/80	15/35	.05	.05
Grouser	20/30	40/70	15/35	.05	.05

Table 2

Results of Chemical and Physical Tests of Five Heats

C	Mn	Si	P	S	Yield point pounds per square inch	Tensile strength pounds per square inch	Per cent Elongation in 2 in.	Per cent Contraction of area
					Links			
.40	.57	.31	.037	.029	53,000	91,000	15	20.5
.35	.50	.25	.05	.038	59,250	91,000	22	30.7
.35	.52	.34	.046	.029	56,500	84,500	18	34.0
					Grousers			
.24	.45	.30	.031	.023	46,500	71,000	22.5	37.2
.26	.46	.21	.032	.024	46,250	71,500	25	37.2

Melting Practice

The steel for both types of castings was made in a two-ton acid electric furnace. Acid steel was used in preference to basic because of the higher temperature and greater fluidity obtainable in the acid furnace, this being necessary due to the thin sections of the castings and the larger number of molds poured per heat.

The foundry operates a six-ton basic electric furnace for the general run of ordnance castings and scrap, in the form of gates and risers, from the basic furnace together with sufficient steel turnings from the machine shop to properly balance the charge was used in the acid furnace. This gave a fairly clean charge, though most of the turnings were slightly coated with rust. Approximately one-third of the charge was made up of these turnings.

As soon as the charge is entirely melted, a fracture test is taken and slowly cooled in water. This is read for its carbon content and the bath recarburized with low-phophorus low-sulphur pig iron to approximately the desired point. Sufficient time is allowed for the pig iron to melt and the bath then thoroughly rabbled. A test is then taken and sent to the laboratory for carbon and manganese analysis. Approximately twenty-five minutes is required to take the test out of the furnace, cool it, send to the laboratory through a pneumatic tube and receive back the result. While waiting for the results from this test, the slag is worked with lime, manganese ore and coke when necessary. On a large number of heats run in this furnace it has been found that coke can safely be used as an aid to deoxidizing the bath when the slag is fairly heavy without danger of reducing the silicon and thereby running the silicon content of the bath up beyond the desired point.

Every effort is made to bring the slag to the proper condition, robins egg blue or green, by the time the test is received back from the laboratory. In the meanwhile the temperature of the bath is gradually brought to the tapping point, so that when the test is received the heat will be ready for the ladle. On the basis of the test sent to the laboratory, supple-

mented by a fracture test taken about the time it is expected back, the bath is recarburized to the carbon content aimed at or slightly above. If conditions have been right and the bath has been properly worked, the temperature of the metal will now be at about the tapping point and the bath should be slowly picking up silicon. The ladle is then called for and the proper amount of ferromanganese added. A final temperature-silicon test is taken and on the rare occasions when it is necesary ferrosilicon is added to bring the silicon content up to the desired point. Approximately one pound of aluminum is added in the ladle per ton of steel. Temperature is judged throughout by pouring from a spoon under as nearly standard conditions as possible.

No heat is tapped out except when the slag is in proper condition. On occasional heats this makes necessary the sending of a second test to the laboratory. On occasional heats the silicon content will run up too high early in the heat. When this occurs use is made of iron ore and manganese ore to oxidize the silicon. This occurs as a rule because the heat has been melted down too hot or else run too hot in the first few minutes after melting.

It is believed that the best steel is made in the acid furnace when the temperature of the bath and the condition of the slag are so controlled that when the test is received back from the laboratory, the silicon content of the bath will be correct within limits and the slag will show the proper color. The heat is tapped into a teapot spout ladle and shanked from it into bull ladles handled by two men. Up to seventy-five links and approximately two hundred grousers are poured per heat.

The above remarks relative to silicon pickup are intended to apply to heats of steel made for the class of castings described in this paper, that is to metal that must be finished very hot in order to run the thin sections and stand up long enough to pour the required number of molds. Where the class of castings to be poured does not require very hot metal, there is not the same opportunity to control the silicon pickup.

Discussion—Production of Light Steel Ordnance Castings

J. A. Anderson.—I would like to ask how many of those links do you get in a day?

Captain Minton.—About 50 with a machine molder and a helper. That was on piece work. I think that was an average figure; in fact I think we got up to 65 at times.

Mr. Fabre.—What capacity furnace was used and how many heats did you get in 24 hours?

Captain Minton.—The furnace was rated at two tons capacity and up to four tons. On this class of castings we only ran about two tons of metal in the furnace, because that was about as long as the metal would stand up to pour this type of casting. As I said before, most of our castings were made in the basic furnace, and only on special types like these did we run the acid furnace.

A Member.—Did you run the acid furnace continuously for twelve hours?

Captain Minton.—No, we could not do that; we ran sometimes as many as 3 heats a day, sometimes only 1 heat a day. With a cold furnace, we are pretty fortunate to get the heat out in 3½ hours. Following one heat with another, we get them out in 1½ hours to 2½ hours. Most of that time is taken in melting down.

F. B. Poto.—I would like to ask Major Minton what was the object of adding that aluminum?

Captain Minton.—The only object we had in adding the aluminum was to take care of any oxides that might be in there.

F. B. Poto.—In case of slag, did you aim to get any certain composition to eliminate the iron?

Captain Minton.—The main thing was to get the iron out of the slag.

Chairman C. S. Koch.—Just before the meeting, the major was telling me about some of the work they have done out there on X-ray analysis. That is something we are all interested in, and perhaps you would like to have him tell you something about that.

Captain Minton.—I thought that question might possibly come up. They have installed an X-ray machine in the laboratory which is good for photographing through steel castings 3 inches thick; that is about the heaviest section they have gotten through successfully so far. Any sand holes, trap sand or blowholes or any interior cracks, anything of that kind is shown up absolutely cold by the X-ray. The tube that we have is rated about 200,000 volts, and with 200,000 volts we get a picture through about 2.9 inches of steel. By varying the exposure somewhat, you get through a little thicker metal. Now the ordinary exposure for thin castings will be about 3 minutes; on the heaviest castings it will go up to as much as 30 minutes.

Core Mixtures for Light Steel Castings

By C. S. Kock, McKeesport, Pa.

The object of this paper is not to cover the entire field of making cores for light steel foundry work but is rather to give in a general way, the results of an investigation made at the plant with which the writer is connected at the instigation of the Electric Steel Founders Research Group.

The research was not started for the reason that the cores which the group as a whole were making were not satisfactory, but rather to determine if it were not possible to reduce cost of core mixtures and also to reduce costs by the use in the cores of more so called heap sand than formerly had been the practice. Other points were also to be considered such as temperature and time of drying, percentage of moisture in cores and all other matters pertaining to core making which might facilitate output.

In such an investigation two important measurements were necessary for every mixture tried namely the strength of the core and the cost of the mixture, with a result that a very small tensile test machine was developed by which regular shaped bricquettes were pulled but which bricquettes had a breaking section of only one quarter square inch that is one-half inch on the side instead of the more commonly used inch square bricquette and the cost matter was taken care of by figuring the actual cost of one hundred pounds of mixed core sand.

Accordingly, a test sheet was made out for everyone of the mixtures tested and on this sheet were given the tensile strength of the cores and the cost of the mixture as well as much other information regarding methods by which the sand was mixed time and temperature of baking and all other details concluding with a statement as to the quality of the resulting cores.

It will be noted that the permeability of the cores is not included in the above mentioned details. This is due to the fact that in the early months of this investigation, repeated tests were made on the permeability of the cores by one of the well known methods of permeability.

Results showed that all cores made with the sand and ordinary core mixtures on the market came well within the practical requirements. It of course showed that different sands and different binders gave somewhat different degrees of permeability, but the open sand used by well known foundries is so far within the allowable limits of permeabilty that we could not even determine what would be a danger point.

This of course applies to the vast majority of cores. Some cores with a very small opening thus allowing insufficient venting might prove exceptions to the above.

It will be impossible in a short paper such as this to give detailed results of more than a small portion of the work done, and little will be stated about such mixtures and methods which did not prove satisfactory, but rather the bare statements of such things as were found to be of sufficient value to be introduced into our practice.

Cost of Core Mixtures

This paper deals essentially with economies and the value of core mixtures. It is probably true that few foundrymen know the cost of their core mixtures. They may be familiar with cost of core mixtures per ton of castings. However, in order to properly determine the choice of core mixtures to be used for different purposes, the value of each mixture for one hundred pounds, should be figured.

Taking the value of 75 cents per gallon for commercial oil mixtures, and with a mixture of one to forty of sand, and using the value of $3.50 per ton for the new sand one hundred pounds of core mixture costs 32 cents for materials only.

To compare with this, let us consider the value of one hundred pounds of core mixture made from heap sand, with a pitch compound as a binder, using the value of 2¼ cents per pound for the pitch compound and nothing for the value of the

heap sand, which in most foundries is thrown away, being in excess of that necessary for molding. The value of that mixture is 3 cents per one hundred pounds.

Now assuming that it were possible, which is not, to entirely substitute such pitch cores for oil sand cores, and assuming the figure of 800 pounds of core mixture per ton of castings, it will be readily seen that a reduction in cost per ton of $2.32 could be made.

On a tonnage amounting to 500 tons per month, this saving would be $1,160.00 per month. If oil continues to rise the saving would obviously be greater.

It is entirely probable, however, that for a foundry such as the one with which the writer is connected, it is advisable to use three general core mixtures, depending entirely on the cores in question, and these mixtures are as follows:

First—The best possible oil sand core amounting to 15 per cent by weight of the total core mixtures.

Second—A medium priced core mixture using corn flour binders with 50 per cent new sand, for about 35 per cent by weight of the work.

Third—Still cheaper pitch or paper mill by-product cores with only one-third new sand for possibly 50 per cent of the work.

Extreme discretion should be used as to the relative proportions of the three mixtures used. In no case should a cheaper mixture be used if quality of the product is thereby affected, but it appears to the writer that the past history of the steel foundries on light work has been, that practically all the cores have been made from expensive oil mixtures using all new sand, although a large percentage as stated before could be made of cheaper mixtures.

It may be of interest to know that for some months our foundry ran on a combination of 90 per cent pitch compound cores and 10 per cent of a somewhat more expensive core mixture, and with practically no oil sand cores.

It is not believed, however, that such extreme percentage of cheap cores is advisable in ordinary practice. The conclusion

of this investigation was not to be made from laboratory experiments or short tests, consequently, very cheap cores were used for considerable lengths of time, although it was realized we had possibly gone beyond the danger point.

At this point, it might be stated that the use of cheaper mixtures, than oil sand mixtures, required much closer attention on the part of the executive of the foundry, than if a core shop were run on only oil mixtures.

It is human nature, for those who are not directly financially interested to desire the use of such materials as more or less the care of themselves. The making of cores with a large percentage of heap sand, and with cheaper core compounds requires the close co-operation of the molding department and the core department, with a desire on the part of all to make such savings possible.

To anyone not particularly interested in making a financial saving, this paper is of little interest and perhaps the conditions which exist today are not such as to lead most persons to be particularly keen regarding savings, but, this investigation was started some two years ago when everyone was endeavoring to save every dollar possible, and there is no telling when we will return to a like situation.

It is quite possible with the proper selection of cheaper mixtures to reduce the cost of core mixtures, $1.50 per ton of castings. The values of materials remaining as they have existed for the past six months, and with the present mounting cost of linseed oil, this figure can probably be raised to $2.00 per ton. Based on a production of 500 tons per month, it can readily be seen that this amounts to a considerable item, and well warrants any foundry in taking up the question of cheaper substitutes for oil sand cores.

It should be understood that the results which are here given are the actual findings. Anyone connected with these results is interested in no other matter than to determine which compounds are best.

It can be here definitely stated that there are no better cores than those made from a proper proportion of suitable sharp

sand and a good core oil, and the only objections to them are, the cost of the binder the time required for baking, and for certain cores, the lack of green bond.

As the remainder of this paper will deal more or less therefore with economical substitutes for core oils, those favorable to core oils should not feel that they have not received their fair share of consideration, and that the general good qualities of oil cores are not appreciated.

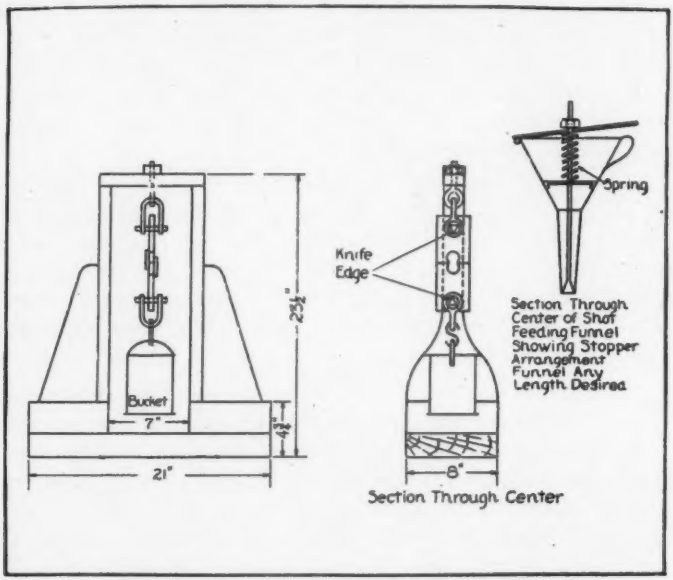

FIG. 1—CORE BRIQUETTE TESTING MACHINE USED IN DETERMINING THE TENSILE STRENGTH, CORES MADE FROM THE CORE MIXTURES INVESTIGATED

After an oil core is made it has every requirement of an ideal core excepting one; namely its inability to yield on contraction of certain intricate designs thereby producing cracks. A properly made oil sand core has among other characteristics the ability to be stored for a great length of time and in green

sand molding, it absorbs less moisture from a mold than any other kind of core.

It was found, however, after trying literally hundreds of mixtures in varying proportions under all conditions that extremely fine cores can be made at a reasonable price by a substitution for oil or for part of oil corn flour binders. Their value rests in the fact that they will carry any degree of heap sand up to 100 per cent.

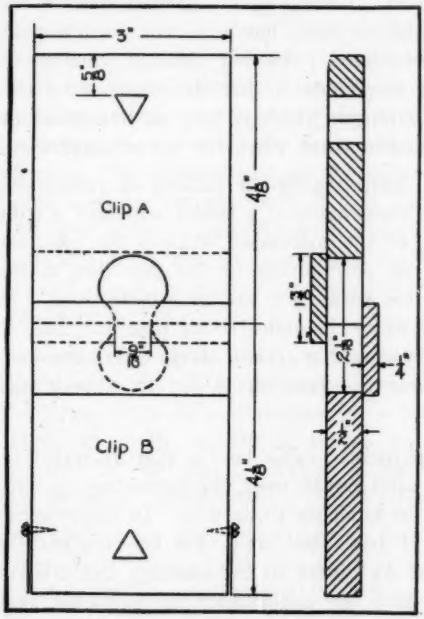

FIG. 2—DIAGRAM OF CLIPS TO HOLD CORES IN TESTING MACHINE

Comparison of Quality of Core Mixtures

Cores made from them dry exceedingly rapidly. The absorption of moisture during storing is practically nothing, and the absorption of moisture in the mold although considerable in excess of that of the oil sand core, has not been found suffi-

cient to give any bad results. For example, cores have been left in green sand molds for 66 hours, and while the cores at the end of that time appeared to have a skin which contained more or less moisture, it could not be found in any case this affected the appearance of the castings.

Cores made from these compounds have another exceedingly desirable quality, namely, that they have a yielding power to the contraction of the castings, in excess of any other core compound used. Peeling quality of such cores is not quite equal to that of the oil core, but in most cases, is sufficiently close not to be considered. Another desirable quality of cores made from these compounds is that the core sand has an increased green bond strength which is very advantageous in the making of certain shaped cores when the use of dryers is not possible.

For the same reason the making of certain cores with the use of these compounds as a binder will take a trifle more work on the part of the coremaker, than is the case with a straight sharp sand oil core owing to the fact that in bumping small core boxes, the packing is not as rapidly done. However, this objection is more theoretical than practical, and this objection will have affect only in certain shops where the speed of making oil sand cores has been developed to a very high degree of efficiency.

Their particular value lies in that as stated before considerable heap sand can be used, the percentage of which is entirely affected by the tendency to burn in. In other words, the greater proportion of new sand used, the less tendency will there be for the sand to adhere to the castings and consequently, these compounds give an opportunity to vary the relative amount of new and heap sand as the requirements of the case in question. Cost per one hundred pounds of core mixture using one part of new sand and part old sand and a 1 to 40 ratio is 15 cents. Obviously the less new sand the cheaper will be the mixture.

Another substitute for oils and found extremely economical is that of so-called pitch compound. It is possible for a foundry to make cores with air floated pitch of good quality without the

addition of any other compound but it is quite probable that the addition of a certain amount of other ingredients to the pitch is of assistance in the manner in which the cores release themselves from the castings.

This having been a well known fact for sometime, various pitch compounds are sold with varying proportions of pitch and said other ingredients. This matter has even gone so far that the purchaser may specify the per cent of other ingredients he desires in the compound.

A core mixture using a pitch compound and all heap sand can be made for 3 cents for 100 pounds. And again, as in the case of corn flour binders any amount of new sand can be used, depending entirely on the necessities of the case. The price mounts as the proportion of new sand. At one third new, the value is 9 cents. The addition of a portion of new sand raises the cost of this mixture, but obviously it will not approximate the cost of oil sand cores, because three quarts of a pitch core compound costs 2¼ cents and has practically the same bending power as two and one half quarts of oil compound at 75 cents per gallon, or 49 cents.

In determining the cores which would be made of this extremely cheap mixture, it is perfectly obvious that these would be the larger ones with consequently, a large saving in material. This fact is the reason as before stated that it is very probable that 50 per cent by weight of the cores in our foundries can be made advantageously from pitch compounds.

The other qualities of pitch cores are that they absorb practically no moisture in storing, and that their strength does not materially decrease during storing, and they do not absorb any unreasonable amount of moisture from the green sand mold during a period of 48 hours, which is practically longer than cores remain in molds before pouring.

The green bond strength of these cores is entirely dependent on the strength of the heap sand, as pitch in itself adds little if any green bond. If the heap sand is not sufficiently strong for the coremaker to use rapidly, the green bond strength can be increased by a slight addition of corn flour binders.

A very desirable quality of pitch cores is the rapidity with which they can be dried, and this feature will be brought out more definitely later in the paper when the drying time of various mixtures is discussed.

Recently we have found that a satisfactory and at the same time a very cheap core can be made using paper mill by-product with heap sand. Again any amount of new sand can be used. The value of 100 pounds of such a mixture without any new sand is 1 cent.

Many believe that paper mill by-product cores are likely to absorb too much moisture while standing in the green sand molds. This may be true in certain localities, but as stated before if only a judicious amount is used, this is not as dangerous as may be imagined. Experiments made by us have shown no evil effects from a core which had outer coatings containing considerable moisture.

It will thus be seen that it is possible to substitute for an extremely costly oil compound, other classes of compounds in a large percentage of the cores made. The degree to which this can be extended is entirely dependent on the degree of watchfulness of the organization and their desire to save money.

The matter can be pushed to such an extent that the cheaper cores are used in places where they should not be, with a result that the quality of the castings is harmed to the extent that excessive cleaning costs result, and possible to the point where a large amount of pitch is introduced into the heap sand of the foundry.

The writer hesitates to mention this last fact, as it is one which has not as yet been definitely determined at the plant with which he is connected. The matter was carried to the extreme. That is, a very large portion of the cores were made of pitch compound, and owing to the fact that the production of the foundry was being greatly increased more heap sand was needed, and consequently, the cores were not separated from the heap sand. This was a most severe test and whether or not the heaps were injuriously effected is questionable.

There were slight indications at one time that an excessive amount of pin holes and small blows were evident, but as

these have happened before, when no pitch cores were used, it cannot be definitely stated that they resulted from the use of pitch cores.

Table 1

Costs of Sand Mixtures Tested

All oil—All new sand	1	to 40	—32 cents
Corn flour binders—All new sand	1	to 40	—22 cents
Corn flour binders—50 per cent new—50 per cent heap sand	1	to 40	—13 cents
Pitch compound—All heap sand	1	to 40	— 3 cents
Pitch compound—33 per cent new—67 per cent heap sand	1	to 40	— 9 cents
Paper mill products—All heap sand	1	to 40	— 1 cent
Paper mill products—33 per cent new—67 per cent heap sand	1	to 40	— 7 cents

The remainder of this paper will be devoted to some other features of core-making, such as the percentage of moisture, the temperature and rate of drying, of various kinds of cores.

This part of the investigation covered a great length of time, owing to the fact that if the figures were to be of any use, standard methods of testing had to be adopted.

As example, it will be noted on the charts shown later that the percentage of moisture in the core mixtures is frequently given, as it was found that different core mixtures required slightly different percentages of moisture before being made into a core to yield a maximum strength. Consequently, these determined percentages were used in each case.

It should be noted of course that in making such comparisons the cores had to be made in such a way that they were uniformly rammed. It is obvious that the harder the core is rammed when other compounds than oil are used, the stronger will be the core, and this is all of such consequence that a great deal of time was spent in making cores which could be compared.

It was found possible to make cores from a box so arranged that the given weight of sand could be compressed into a bricquette core, or from a given volume of sand, because as has been found in the investigation on cohesiveness tests carried

on in the sand investigation, different sands are compressable to a different degree.

It was found, however, that uniform cores could be made by O. H. Frederick, who conducted practically all these experiments and to whom due credit is hereby given.

Ten cores made from a given mixture varied only a slight amount from the average. The limits of variation were well within other errors liable in the consideration of the subject.

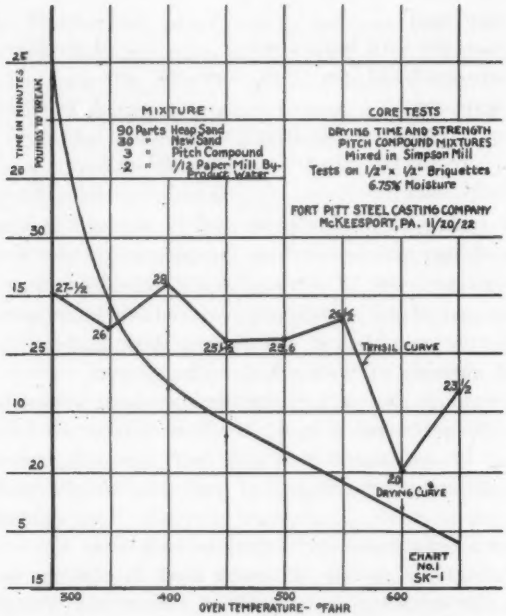

FIG. 3.—CHART NO. 1 SHOWING STRENGTH OF PITCH COMPOUND CORES AS AFFECTED BY DRYING TIME.

Explanation of Charts

Chart No. 1 illustrates two different features. The curved line indicates the time required for drying at different temperatures, the cores being perfectly dry. The core mixture used was 90 parts heap sand, 30 parts new sand with 3 parts pitch

compound as a binder. The sand was mixed in a muller, and before being made into test cores, contained 6.75 per cent moisture. The temperature line shows that the time of drying decreased very rapidly as the temperature increased up to approximately 400 degrees, after which the speed of drying did not increase as rapidly. The line representing the strength

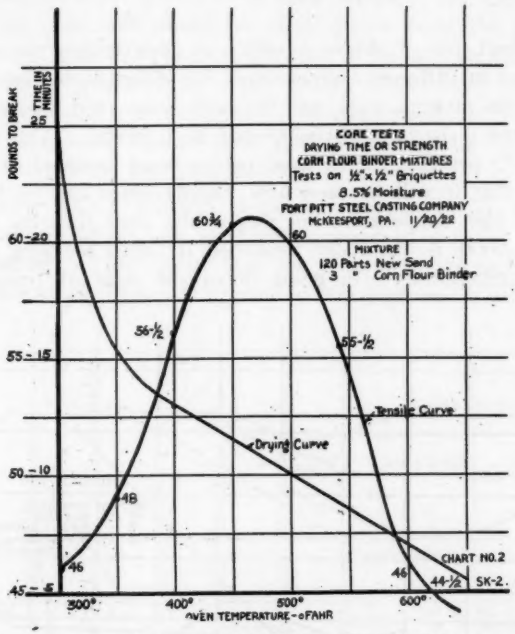

FIG. 4—CHART NO. 2, SHOWING STRENGTH OF CORN FLOUR BINDER CORES AS AFFECTED BY DRYING TIME

indicated that the strength remained about the same unless the temperature was over 550 degrees.

Chart No. 2 is similar to No. 1, except that the mixture was all new sand with a corn flour product as a binder, at the ratio of 1 to 40 the moisture of the sand being used was 8½ per cent. As in the preceding chart this also shows that

the time of drying decreased very rapidly up to 400 degrees and very slowly thereafter. As for the strength of the cores, it showed that possibly 450 degrees Fahr. gave a maximum strength and that the strength decreased thereafter. However, it brought forth one point not shown on the preceding chart, which is that in the case of the corn flour product as a binder, satisfactory strength was not obtained until 450 degrees was used.

Chart No. 3 shows a series of tests giving the strength obtained at different temperatures for different baking periods. The core mixture used was 90 parts heap sand, 30 parts new sand and 3 parts pitch compound as a binder. The moisture was 6.75 per cent in the sand before being rammed into cores. From this it will be seen how rapidly cores can be baked at a very high temperature but that at the same time the strength of the cores is materially weakened if baked too long at some high temperatures. In going down the scale of temperatures

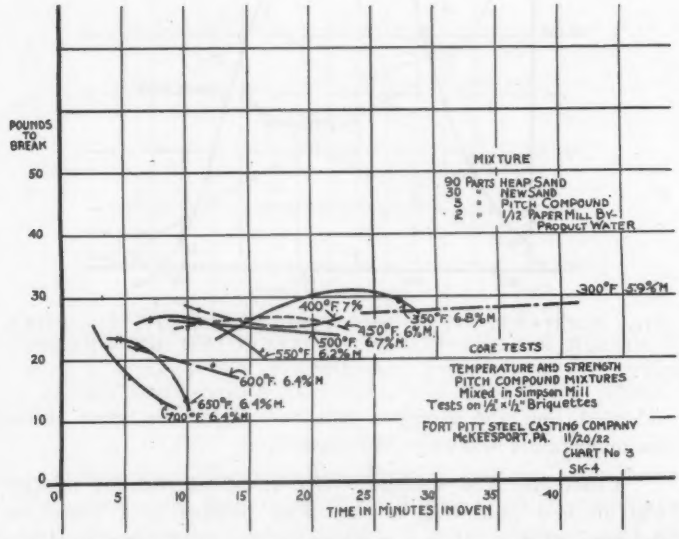

FIG. 5—CHART NO. 3. STRENGTHS OF PITCH COMPOUND CORES WHEN BAKED AT VARYING TEMPERATURES

from 700 degrees it will be seen that this line does not become horizontal until 500 degrees is reached. From 600 degrees to 300 degrees there is appreciably no decrease in the strength of the cores unless they are left in oven an unreasonable length of time after they have come to the dried condition.

Chart No. 4 indicates the same features as No. 3, but the sand was all new with a corn flour binder. The conclusions from this chart are similar to those drawn from the previous one, except that 500 degrees appears to be a somewhat more dangerous temperature at which to dry these cores than was the case with the pitch compound. In other words, a 500 degree line in the case of the core flour binders approximate 550 degree line in the case of the pitch binders.

Chart No. 5 indicates a similar experiment in the case of a mixture of all new sand with a ratio of 1 to 40 core oil as a binder. This shows that the maximum strength is obtained anywhere from 400 degrees to 500 degrees. It also shows

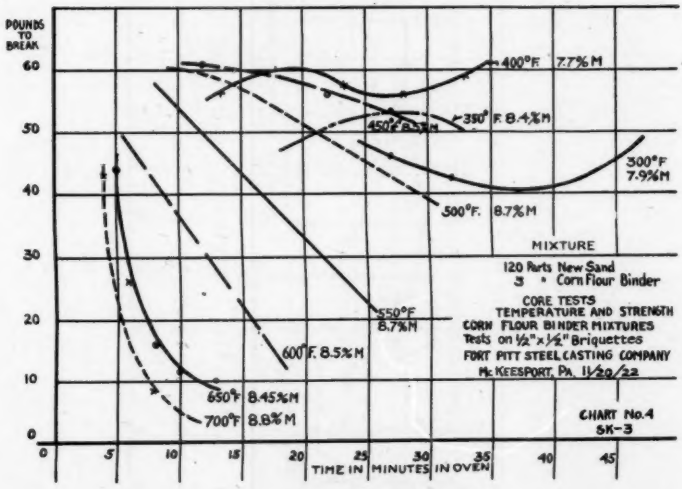

FIG. 6—CHART NO. 4. STRENGTHS OF CORN FLOUR BINDER CORES, WHEN BAKED AT VARYING TEMPERATURE.

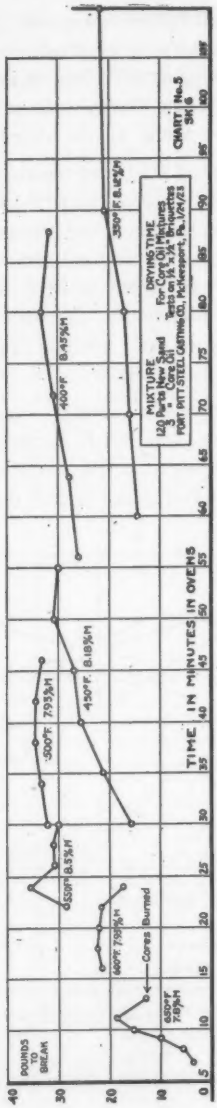

FIG. 7—CHART NO. 5. DRYING TIMES FOR CORE OIL MIXTURES

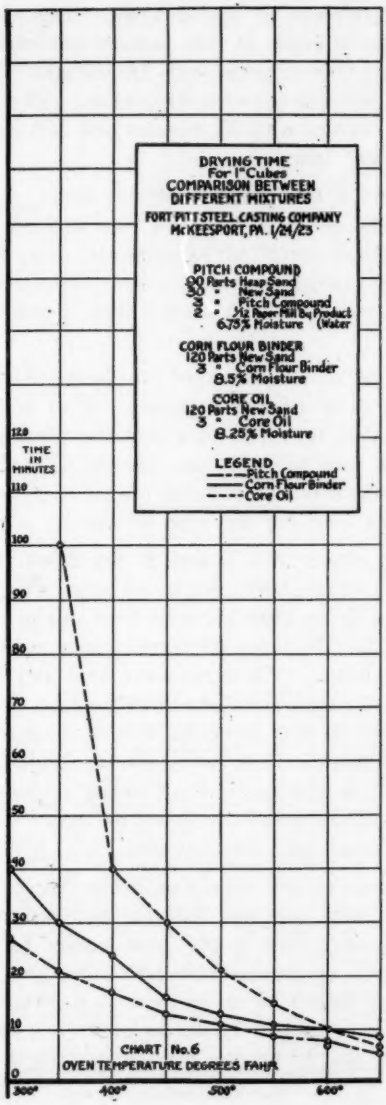

FIG. 8—CHART NO. 6. COMPARISON OF DRYING TIMES OF CORES MADE OF PITCH COMPOUND CORN FLOUR BINDER AND CORE OIL. TEST CORES 1-INCH CUBES.

the remarkable difference in drying times. This chart shows that the maximum strength at 650 degrees was obtained with 12 minutes baking, 600 degrees with 18 minutes, 550 degrees with 23 minutes, 500 degrees with 40 minutes, 450 degrees with 50 minutes, 400 degrees with 80 minutes and 350 degrees with 100 minutes baking time.

Having observed the effect of drying times on the cores as indicated by the previous charts, it was decided to make a separate and distinct series of experiments, and in place of using the ½-inch bricquettes as in the previous cases, this experiment was carried on with cores 1-inch, 2-inch and 3-inch cubes.

Chart No. 6 shows the time required to dry 1-inch cubes made from three different mixtures. They were all dried in the same oven at the same time and the ideal percentages of moisture were used in each case, namely 6.75 per cent for the pitch compound cores, 8½ per cent for the corn flour product cores and 8¼ per cent for the core oil cores.

Referring to charts No. 7 and 8 for 2-inch and 3-inch cubes respectively, they show that in all cases the pitch compound cores dried faster than the corn flour product cores, and the latter faster than the core oil cores at reasonable temperatures. At approximately 550 degrees the lines run fairly close together, but up to that point the difference is one of some importance. It can be seen from this that in those ovens which run at low temperatures the selection of the binder is of considerable moment, as far as time of baking is concerned. It will be seen that all characteristics shown by the cores for 1-inch cubes held for 2-inch and 3-inch cubes.

A consideration of the details on these charts shows that there is an ideal time and that there is an ideal temperature for various mixtures. This is one good reason for not using too many mixtures at one time in core room practice, or in other words there should be in an oven at a given time cores made from only one kind of binder in order to run the ovens most economically and to get the maximum strength from said binders.

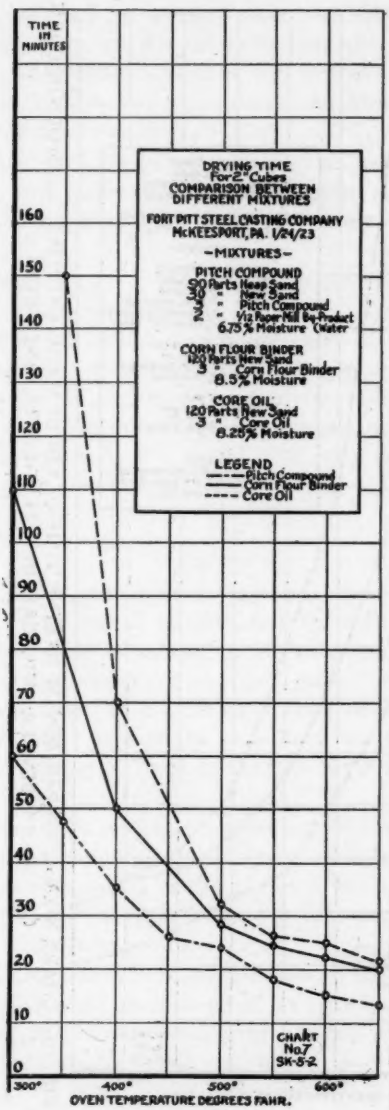

FIG. 9—CHART NO. 7. COMPARISON OF DRYING TIMES OF CORES MADE OF PITCH COMPOUND, CORN FLOUR BINDER AND CORE OIL. TEST CORES 2-INCH CUBES.

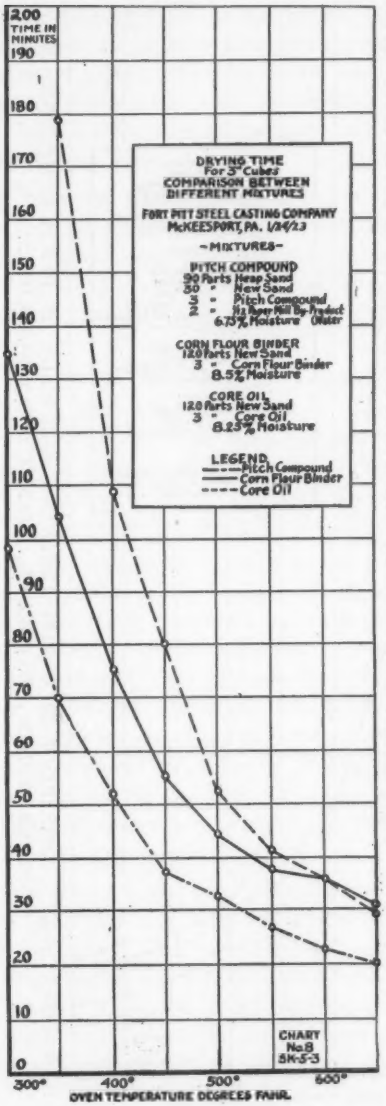

FIG. 10.—CHART NO. 8. COMPARISON OF DRYING TIME OF CORES MADE OF PITCH COMPOUND, CORN FLOUR BINDER AND CORE OIL. TEST CORES 3-INCH CUBES.

Method of Mixing Sand and Binders

Another part of this investigation was the method of mixing the sand with compounds and it was found that in all cases that as regards loss of mixtures, the Muller type of sand mixing machine is the best.

It would take altogether too long to give the results of these tests, but suffice it to say that great economies can be made in the amount of ingredients by use of muller type machines.

It should be noted that all the results obtained were accomplished without the spraying of cores. This subject is an extensive one in itself. Conclusions arrived at however are that the quality of cores is materially increased by proper spraying. This is particularly true in the case of small cores. Reduction in the amount of core binders can be made if proper spraying is practiced. We found that possibly of all known sprays, the best was one of water with an addition of a small portion of paper mill by-products.

Conclusions

Consequently, when all is said and done, and if a new shop were to be started on the class of work similar to that made by the foundries making small steel castings, the writer would from investigations we have made simmer down all well known practices to the use of a small amount of oil cores, a somewhat larger amount of corn flour binder, and possibly 50 per cent of cores from pitch and paper mill by-product compounds.

These mixtures would be properly milled in a muller type of sand mixing machine, and oil sand cores would be mixed with a degree of moisture of 8¼ per cent, and corn flour binder cores would have a moisture content of 8½ per cent and pitch cores of 6¾ per cent moisture.

To any of these core mixtures which at times appeared to be somewhat weak the amount of the core binders would not be increased, but for the time being a small amount of paper mill by-products water made up of one part compound and twelve parts of water would be added, watching very care-

fully that the addition of this mixture did not render the cores too susceptible to an excessive absorption of water in the mold. Practically all the cores would be sprayed with paper mill by-product water of the above proportions, and as most of the cores made of oil sand would be small, they would be dried at a temperature of 500 degrees in an oven through which an excessive amount of air was passing. Corn flour binder cores would be dried at the same temperature, unless they were rather large and the pitch cores would be dried in ovens at a temperature of 450 degrees. The amount of air passing through the ovens for the last two cases would not necessarily be as great as in the first.

The percentage of core binders as in the above cores is not given owing to the fact that this materially changes due to the sand used and to the amount of heap sand available. Any foundryman should be able to determine this for himself.

There would be run in connection with this core room periodic tests of the cores as taken from the coremakers benches for its tensile strength, by a simple testing machine, a sketch of which is attached, in order that errors in mixing and changes in the quality of core binders could be watched.

The testing machine would also be used to test out numerous new mixtures which are constantly being brought to the foundrymen's attention in order that a selection of relative commercial product would not be merely in the mind of a foreman as to which was really giving the best core.

In conclusion, this investigation has taught us that the use of this little testing machine will give the greatest return of other known investments in the foundry.

For example, there are numerous core oil binders on the market which prices are within a very slight range, and the difference in their core binding abilities is exceedingly great. This can be determined with this small testing machine.

Again it has been known to be a fact that the binding qualities of commercial core binders change very often from

shipment to shipment and in order to keep this up to a desired standard, no better way is known than to have in operation a small testing machine.

Discussion—Core Mixtures for Light Steel Castings

A Member.—Do you find any distortion of the cores from rapid heating and high temperatures.

C. S. Koch.—That comes in that matter of moisture; I mentioned before that there was an ideal moisture we had to get; if we had too much moisture in the cores, there were two effects, a man could ram them too much and there could be distortion, but the figures I will give later, if we keep within those, we will not find much distortion, but we found trouble with the distortion of cores where there was a high per cent of moisture.

A Member.—Do you have a natural ventilation or forced ventilation?

C. S. Koch.—It happens to be natural in these particular core tests. In the case of oil we found that excessive ventilation is a mighty good thing to help it along. We believe in raising the temperature pretty high and giving it lots of air.

A Member.—Have you any means of taking the moisture out of the ovens?

C. S. Koch.—In running small cores, our cores are in there 12 or 15 minutes; the cores are put in this side of the oven and taken out there; the result is the doors are opened very frequently. The doors do not fit very well; we allow that because we want to get all that air through there, and we are undecided whether it is better to dry cores that way than to put them on big racks and move them into the oven. In that

way, you can take out some of the smaller cores quicker than the heavier; the labor is a trifle more, but it is more satisfactory, but we have no mechanical method of drawing the moisture out of the oven.

F. J. Ryan.—You spoke about why the oven builder established a rating so low; I think it is probably all the way around; it is the core maker that really established the original temperature, because it seems quite a general term that those lower temperatures were the ones that were advocated in a great many foundries, and recently the higher temperatures have been used. Of course, the results came later through circulation because it is hard to fire with gas or oil and distribute your heat without getting circulation. There you get distribution of heat.

C. S. Koch.—I asked the oven people why they were running 320; they did not say that they advocated it nor that the foundrymen advocated it; they did not seem to know how it did happen.

F. J. Ryan.—I think it has just been one of those things that has just grown up. It is only a few years ago that the foundryman began building his own ovens and I think it was one of those things that have just kind of grown up and we take it as a natural conclusion.

C. S. Koch.—When I told this to somebody they said it was natural for the oven man to talk 300 or 320, because it took quite as much or more oven capacity to do the same work.

F. J. Ryan.—That is not so, but it is extremely interesting from the paper to see where you could reach a maximum limit, because if it is possible to put a core automatically through an oven in five minutes at 700 degrees without distorting it, that is the way to put it through. It is an extremely valuable point. There is no doubt that higher temperatures can be used than have been used in the past. I know one of them, especially down in New Jersey, where they are drying cores now in one-third of the time that they previously dried them, the same cores and in the same type of production, except they have got circulation in their oven and they apparently have the same temperatures that they had in the oven before.

Mr. Hamilton.—Did you take any notice how those cores came out of the castings?

C. S. Koch.—We ran a series; we have a certain sized sample test casting that we put these cores into, and we may have cores made from three different binders in the same flask; the facility with which they peel is a matter of individual opinion; as stated here, oil cores will always come out best; the next is the corn products and the third is the pitch binder, and that is where the discretion comes in as to which cores to use. The whole trouble is this; many of us have been having a big slab core on top of something and making it out of 32 per cent compound. I think that most of our shops have been using a very large percentage of oil cores. The core might be nothing but a block. Another thing, by the use of this little machine, we can reduce the number of core mixtures in our foundry.

C. H. Gale.—The amount of moisture—is that determined by the weight or volume?

C. S. Koch.—By weight. We take, say, 100 grams of sand or whatever it is, and heat it to 105 degrees for, say, an hour, and find the amount of evaporation in that way. Now those limits seem to be pretty small, but you would be surprised to see the difference in pounds between 6 per cent moisture and 8 per cent. We have had so many figures that I tried to eliminate all reference to pulling strength, because it would get involved, but the difference between 6 per cent and 8 per cent in any core mixture will make the difference between a good binder and a poor one.

R. A. Bull.—A question was asked as to the peeling qualities of those various mixtures. As Mr. Koch has pointed out, these cores were not sprayed. Any conclusions which might be reached from Mr. Koch's answer to that question as related to the data illustrated ought to be taken into consideration in connection with another very important factor, that of peeling; a factor that is not included in these data; it could not be, because it would be a disturbing element introduced in the considerations involved.

C. S. Koch.—I might say that my reference to the fact that we did not spray those cores only refers to such cores as

we tested for strength. When we tested a core for its peeling qualities, we did spray it; that was the way it was going to be used, but numerous tests all showed the same thing, that oil was the best, corn product next and pitch last. Of course, the more new sand we put into these other mixtures, the better were the peeling qualities.

N. T. Booth.—Did you make any experiments at all on the combination of corn product and oil?

R. J. Doty.—I might answer this question by stating that in our practice, we want the advantage of oil in certain cores; we also want the advantage of the corn product because of the economy. One of the most popular mixtures in our plant today is a combination of oil and corn product.

C. S. Koch.—We have used that in certain cases where we found the oil cores would crack the castings. Any combination can be used; I went from one extreme to the other, but corn product will mix with oil in fine shape, and so will the by-products from the paper mills. I think the most surprising thing, however, was this moisture in the green molds. We have been afraid of some of these products; so we made our molds and left them in 66 hours; examined them every 24 hours; every day they were getting wetter and we supposed those cores were no good, until we took a chance at casting them and were so surprised to find in a case of small cores that that moisture is not so harmful as we feared, this has been backed up by the experience in a certain malleable shop. Also in discussing this matter of the absorption of moisture with different foundrymen, we found it was very different in different localities; some localities in the river bottoms, it seems to have very much more effect than if it is in a dry climate.

Mr. Hamilton.—I have been very much interested in this matter of the drying temperature and it seems to me that a good deal depends upon the nature of the binding material that is used, as to how high it would be safe to go unless you were watching the cores very carefully. For instance, if you would make a core out of sand and clay, the clay would stand approximately 800 degrees Fahr., but still have its bonding properties, but if you went to a corn product core compound, you would

have about 400 degrees there as a limiting temperature as compared to the 800 degrees, and unless those cores were watched carefully at, say, 500 degrees, it occurs to me there would be a great chance of having a lot of burnt cores; whereas if the core was made out of clay and sand or pitch and sand or linseed oil, which will stand 600 degrees, there would be very little danger of losing cores through burning, and, of course, the matter of the section would come in, which is not considered in your small cores, but would be a very vital thing in a great many foundries where different sized cores were dried in the same oven.

C. S. Koch.—If you can remember, one of those plots started at 700 and the strength went down very rapidly, and when you got to 450 the line became almost horizontal, showing exactly what you mean. Again you see this is rather restricted, in that it applies simply to the sizes of cores, etc., used in a foundry on light work. I tried to get that in the paper. What you say is absolutely true, it is just a question of how fast you want to run; the faster you run, the more careful your oven man has got to be. If you want something to take care of itself and be automatic, which our men usually want, you can dry at 320 degrees and won't burn any cores. We found that to get the maximum strength, we had to go up to 400 degrees, I believe, in almost every case, so that, by and large, 400 to 450 degrees is the most ideal; it is not the fastest, but if you go too fast, you are going to get into trouble. You spoke of having different sections in your cores, but as Mr. Neal says, we are trying to get something as a basis to work on.

Report of the Committee on Specifications for Steel Castings

During the World War, many steel foundries found themselves called upon to make, and to their surprise, found that they could make, castings which should meet physical and chemical specifications. Other steel foundries to which specification work was no novelty, made the production of such steel the order of the day instead of a rather infrequent, and generally unwelcome occurrence. As a result, the technique was greatly improved, and the various specifications in use were subjected to searching scrutiny.

It is not strange, then, to find the various organizations that established specifications turning toward the question of revision with a view to capitalizing the experience gained so recently. Last year a joint committee of the American Railway association and American Society for Testing Materials prepared a draft of specifications for carbon-steel castings for railroads which was approved by the two organizations from which the committee was drawn, and was adopted by the A. S. T. M. at its general meeting in June, 1922, as a tentative standard designated as A 87-22 T, tentative specifications for carbon-steel castings for railroads.

According to the rules of the A. S. T. M. tentative standards are given trial for at least a year and then come up for discussion and final approval. It is, therefore, highly probable that these tentative specifications will follow the usual course and be the subject of discussion and vote at the annual meeting of the American Society for Testing Materials to be held in Atlantic City June next.* Your committee urges earnestly that all members interested study these specifications carefully and, if members of the A. S. T. M., make on the floor of the meeting there, such comments and suggestions as will be helpful. If not members of the A. S. T. M., they are invited to send their comments to the chairman of this com-

mittee who will see that their views are reflected at the proper time.

Last fall the A. S. T. M., perhaps influenced by the action recited above, decided to study its own specifications for general steel castings, and for that purpose a sub-subcommittee was appointed from subcommittee VIII, which is the steel casting subcommittee of committee A-1 on steel. This sub-subcommittee, on which this association was represented by the chairman of this committee, held several meetings, and finally recommended to subcommittee VIII a proposed revision of the standard specifications for steel castings A 27-21. After long and full discussion these proposed specifications were, with a few minor modifications, adopted for recommendation to the committee A-I on steel. Here they were the subject of full discussion and were finally adopted for recommendation to the American Society for Testing Materials at its general meeting in June next. There full discussion and debate will take place and a vote will be taken as to their adoption as the tentative standards of the A. S. T. M.* A copy of this proposed revision is appended to this report and again your committee would urge that all members of this association interested in steel castings feel the importance of expressing their views concerning this revision, preferably in person, upon the floor of the A. S. T. M. convention, otherwise through this committee.

Perhaps in closing there is no impropriety in mentioning the fact that the federal specifications board has just submitted to various departments of the government and to independent establishments, a draft of proposed specifications for steel castings for use in the purchase of all such material by departments of the U. S. government. This association was included in the list of organizations consulted and the chairman of this committee designated as your representative in the discussion requested, it being expressly understood that any comments he might make in no way committed the association.

*At the meeting of the A. S. T. M. held at Atlantic City in June, 1923, tentative specifications for carbon steel castings for railroads, serial designation A87-22T, were adopted as standard and the proposed revision of specifications for steel castings A27-21 were adopted as tentative standards.

As soon as these specifications are adopted and issued by the federal specifications board, notice will be sent to our members through the Bulletin, with information where copies may be obtained.

As you see, then, this past year has been one of considerable activity; may we not hope that it has also been one of progress?

R. A. BULL,
E. W. CAMPION,
J. H. HALL,
J. B. HENRY,
A. H. JAMESON, *Chairman*

Application of Fuel Oil to the Malleable Air Furnace

By A. Van Lantschoot, Fairfield, Iowa.

It is a well known fact that the use of fuel oil in the air furnace has, to a certain extent, been looked upon with disfavor, mainly because of faulty application and lack of reliable data to prove the merits of a very excellent fuel.

The statements made in this paper are not intended to prove the superiority of the use of fuel oil in the melting process, nor should they be taken in criticism of any other fuel in general use in the malleable castings industry today. Powdered coal, electricity and the usual hand-firing methods, all have their place and because of geographical situation, local conditions, investments involved, character of work, etc., each could easily have greater advantages over any of the other methods known to modern practice.

All statements made herein are based on the writer's several years of melting and laboratory experience while in the employ of one malleable foundry and all data submitted is in accordance with actual conditions existing and the practice followed in the operation of this plant, regardless of the theories or methods in use in the industry as a whole and should be considered as such.

Fuel oil has been tried for several years by various concerns with widely varying degrees of success. Many have had an entirely false conception of the problem and the general thought that a change from coal to oil merely involves the construction of a suitable combustion chamber on top of the grates caused a disregard of very essential features, thereby obstructing the natural and theoretical laws that govern combustion and heat utilization.

In order to obtain the best results from the oil fired furnace, its construction should not only be as simple as possible but all essentials must be in harmony with each other and favor the all important objects; correct furnace atmosphere, proper velocity of the gases and the best possible heat absorption by the scat-

tered charge. High air and atomizing pressures, as well as excessive draft, necessitating radical baffling at the rear bridge wall, should be avoided.

Furnace Construction Is Simple

The melting furnace with details shown in Figs. 1 and 2 is typical of simple construction. In order to give the combustion chamber the desired length a short extension was built on brackets fastened to the end plate of the original fire box. The bung line has a gradual slope from its highest elevation to a

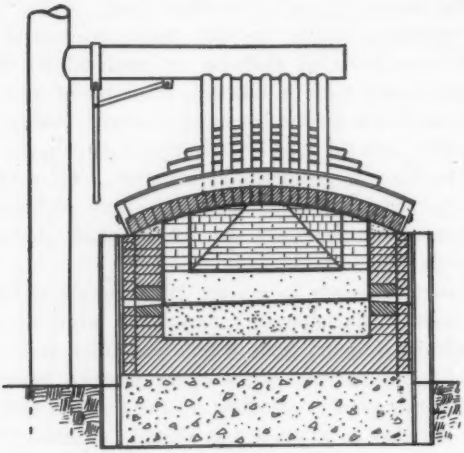

FIG. 1—CROSS SECTIONAL VIEW OF 13-TON OIL FIRED FURNACE

point midway between the front bridge wall and tapping hole; this arrangement promotes a better mixture of the secondary air with the first product of combustion; furthermore, it causes the heat to be deflected upon the charge. The roof above the hearth of the furnace is practically level and no higher than necessary to accommodate a slight excess of the usual charge. A gentle curve beginning at the back charging bung corresponds to the size of the bridge wall opening and favors a desired deflection of the leaner flame upon the extreme portion of the charge.

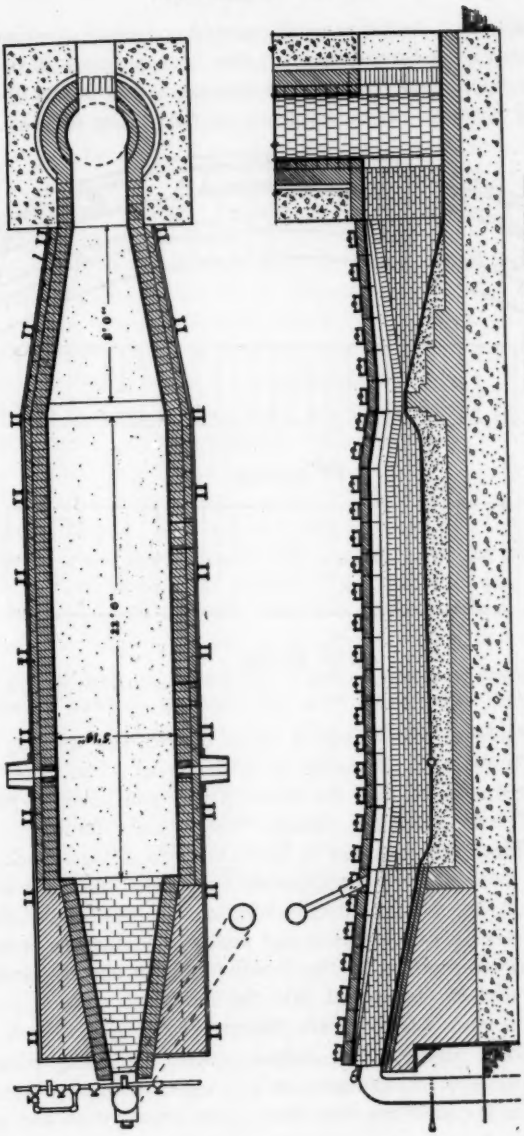

FIG. 2—PLAN AND SECTIONAL VIEW OF 13-TON OIL FIRED AIR FURNACE

The size of the bridge wall opening is largely determined by the action of the furnace gases. Any back pressure through the skimmer door, however slight, is avoided by a corresponding increase of opening. The stack being only fifty feet high and three

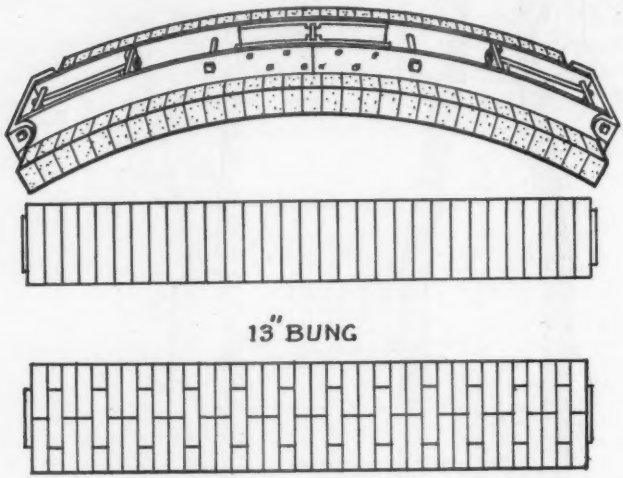

FIG. 3—SHOWING CONSTRUCTION OF FURNACE BUNGS, FRAMES AND SETTING OF BRICK FOR 13-INCH AND 18-INCH BUNGS

feet in diameter necessitates a large bridge wall opening; this feature, however, is desirable as it promotes a uniform speed of the moving gases over the entire charge and tends to prevent excessive heat radiation through bungs and sidewalls. The larger bridge wall opening, in preference to a high stack, also favors a more uniform temperature throughout the furnace, as indicated by the melting effect on the back portion of the charge. The apparent waste of heat in the neck of the furnace is curbed in an effective manner by the function of the checkwork opposite the outlet of the furnace into the stack.

Only One Burner Used

Only one high pressure burner is used for firing purposes. This burner is of the simple, fan tail, external mixing type and has been in constant use for years. The oblong fuel and atom-

izer openings are independent of each other and there is no possibility of clogging or carbon deposition at the orifices. The oil as it passes out perpendicularly under suitable pressure is struck forcibly at a right angle by the steam used for atomizer and a broad, fan shaped flame, corresponding to the shape of the combustion chamber, is produced. Air, at fairly low pressure, is admitted through a twelve inch pipe below the burner, in quantities barely sufficient to produce the first product of combustion. Even a tendency towards carbonization against the combustion chamber roof or a noticeable back firing towards the burner is tolerated without concern. A steam pressure of twenty to thirty pounds is sufficient to atomize the fuel and give the proper velocity to the burning mixture.

The oil is pumped from large storage tanks through a twin strainer into a small preheating tank provided with an air cushion. The pulsation effect, caused by the strokes of the pump, is thus eliminated and a constant and steady pressure at the burner insured. The oil and steam supply pipes leading to the burner are incased side by side in one insulating cover. A temperature of about 130 degrees Fahr., as indicated by the thermometer on the oil line near the burner, seems sufficient to reduce the viscosity of the oil to a free flowing point.

The question of burner superiority is not as important as in most oil burning systems. It is a minor factor and double stage burning is the answer. The most desirable features include, one burner only; simple, rigid construction and freedom from clogging, regardless of design; ease of manipulation and adjustment to conform to the shape of the most suitable combustion chamber, and very important—the ability to atomize fuel of any specific gravity or grade offered on open markets.

In determining the size of the combustion chamber a number of points must be given due consideration. Its length is dependent upon the type of burner, as well as the pressure of the atomizing agent and the blast. A length of nine to ten feet gives the best results in connection with the external mixing burner now in use. The width and height are proportioned to the size of the furnace. The mouth of the present combustion chamber is eighteen inches narrower than the furnace

proper. This arrangement is preferred over full width as it affords ample protection to the side walls and reduces the distance between the top blast pipes, thereby promoting a more uniform mixture of the top blast and the monoxide gases.

Top Blast All Important

The top blast is the important pivot upon which the main essentials of successful operation are balanced. This statement cannot be emphasized too strongly as fuel consumption and time, oxidation and repairs are powerfully influenced by the application of the secondary air supply. Excessive oxidation of the elements especially carbon proved the recognized stumbling block in the early stage of oil melting practice, yet an attempt to remove the source of evil excess air forced in contact with the charge, by elimination of the top air as a whole or in part, lacked effect and proved a waste of fuel and time through failure of the liberated heat to yield its maximum intensity. It should be kept in mind, with oil as fuel, that the incorrect proportioning of the top and bottom blast, necessitated by intermittent hand-firing conditions need not exist and since oil lends itself to a constant and most favorable fuel distribution the logical solution is first to eliminate excess air, and then utilize the great advantage of double stage burning to the fullest extent. The usual 70-30 air ratio therefore is changed, as soon as the furnace temperature permits, to a 50-50 ratio and in order to minimize the effect of this radical change on oxidation the volume of air is reduced to approximately theoretical amounts. It is a matter of choice between two evils, too much or not enough air, and actual results rather than the generally accepted rule should determine the preference. In case a higher oxidation rate is desired, even as much as sixty per cent of the total blast is admitted through the wind bung.

The most complex problem in connection with a balanced air ratio is the difficulty in bringing about a homogeneous mixture of the advancing combustible gases with a theoretical amount of overhead blast. It is of the utmost importance therefore that the top blast be delivered in such a way that the best possible contact of fuel and air results. The desired effect can only be brought about by admitting the overhead blast under fairly

TABLE 1.

CORD OF TWENTY (20) CONSECUTIVE HEATS RUN FROM OIL FIRED FURNACE WITHOUT CHANGING OR ADJUSTING CHARGE AND METHOD OF FIRING

CONTENTS OF CHARGE, 50 PER CENT PIG IRON, 40 PER CENT SPRUE, AND 10 PER CENT MALLEABLE SCRAP

Date	Heat No.	Weight of charge Lbs.	Gals. oil used	Gals. per ton	Fire started	Heat Tapped	Time Per Heat Hrs.	Time Per Heat Min.	Analysis of Charge: Sil. Per cent	Sul. Per cent	Phos. Per cent	Man. Per cent	Total Carbon per cent	Analysis of Hard Iron: Sil. Per cent	Sul. Per cent	Phos. Per cent	Man. Per cent	Total Carbon Per cent	Loss and Gain of the Elements: Sil. loss	Sul. gain	Phos. gain	Man. loss	Total Carbon Loss
11/14 A. M.	290	17000	530	62.5	8:20	11:20	3	0	1.27	.042	.160	.38	3.01	.92	.044	.164	.28	2.51	.35	.002	.004	.10	.50
11/14 P. M.	292	17000	530	62.3	2:20	5:05	2	45	1.29	.042	.159	.37	2.98	.92	.043	.166	.27	2.38	.37	.001	.005	.10	.60
11/15 A. M.	294	17000	540	63.5	8:20	11:20	3	0	1.28	.041	.163	.38	3.02	.96	.046	.163	.26	2.54	.32	.005	.000	.12	.48
11/15 P. M.	296	17000	500	58.8	2:15	5:00	2	45	1.28	.041	.164	.37	2.97	.91	.047	.167	.27	2.58	.37	.006	.003	.10	.39
11/16 A. M.	298	17500	560	64.0	8:15	11:20	3	5	1.30	.042	.162	.37	3.04	.95	.045	.165	.26	2.49	.35	.003	.003	.11	.55
11/16 P. M.	300	16500	530	64.2	2:10	5:00	2	50	1.28	.043	.164	.37	3.06	.94	.047	.173	.24	2.46	.34	.004	.009	.13	.60
11/17 A. M.	302	17000	560	65.9	8:20	11:25	3	5	1.30	.042	.164	.37	3.02	.96	.046	.171	.26	2.48	.34	.004	.009	.11	.54
11/17 P. M.	304	17000	510	60.0	2:15	5:00	2	45	1.29	.043	.167	.36	3.00	.94	.044	.174	.25	2.41	.35	.001	.007	.11	.59
11/18 A. M.	306	15500	520	67.1	8:15	11:20	3	5	1.30	.042	.166	.37	3.01	.88	.043	.168	.24	2.34	.42	.001	.002	.13	.67
11/20 A. M.	308	17500	580	66.3	8:20	11:20	3	0	1.29	.041	.164	.36	2.99	1.06	.045	.169	.27	2.11	.23	.004	.001	.09	.85
11/20 P. M.	310	17000	540	63.5	2:20	5:05	2	45	1.25	.041	.164	.36	2.96	.98	.047	.159	.25	2.37	.27	.006	.005	.11	.59
11/21 A. M.	312	17000	560	65.9	8:20	11:20	3	0	1.32	.042	.165	.37	2.88	1.01	.047	.169	.26	2.46	.31	.005	.004	.11	.42
11/21 P. M.	314	17000	530	62.3	2:20	5:00	2	40	1.30	.042	.161	.36	2.97	.99	.047	.170	.25	2.41	.31	.004	.009	.11	.56
11/22 A. M.	316	17000	560	64.0	8:25	11:25	3	0	1.31	.043	.165	.37	3.00	1.01	.043	.171	.27	2.42	.30	.000	.006	.10	.58
11/22 P. M.	318	15000	500	66.6	2:25	5:00	2	35	1.30	.043	.166	.36	2.99	1.02	.049	.167	.26	2.58	.28	.006	.001	.10	.41
11/23 A. M.	320	16500	540	65.5	8:20	11:25	3	5	1.31	.041	.166	.37	2.99	.98	.046	.164	.26	2.44	.33	.005	.002	.11	.55
11/23 P. M.	322	16000	480	60.0	2:20	5:00	2	40	1.31	.044	.164	.37	3.05	.98	.044	.167	.25	2.50	.33	.000	.003	.12	.55
11/24 A. M.	324	17000	550	64.7	8:20	11:20	3	0	1.30	.042	.163	.37	3.00	.98	.045	.164	.26	2.39	.32	.003	.001	.11	.61
11/24 P. M.	326	16500	490	59.3	2:20	5:00	2	40	1.30	.042	.164	.36	3.02	.97	.048	.162	.26	2.56	.33	.006	.002	.10	.46
11/25 A. M.	328	17000	530	62.3	8:20	11:20	3	0	1.30	.043	.163	.37	2.98	.95	.049	.165	.26	2.53	.35	.006	.002	.11	.45
Average		16750	532	63.5	A. M. P. M.		3 2	2 43	1.29	.042	.164	.37	3.00	.96	.046	.167	.26	2.45	.33	.004	.003	.11	.55

Pouring Time—Morning heats 11:25 to 11:55 A. M.
Afternoon heats 5:00 to 5:30 P. M.

low pressure through a suitable number of large bung openings. With these openings across the entire width of the combustion chamber and not over four inches apart, the effect of the secondary air extending into every direction should be continuous and obviously but a small amount of the combustion chamber gases can escape final combustion. The exact location of the blow bung, the correct angle and size of the blast pipes, as well as the proper air pressure, are very important features and must be determined by repeated experiments. If the air pressure is too weak the blast will not penetrate the gases sufficiently to surround every particle of unconsumed fuel and a low temperature results where intense heat is actually needed.

In determining the pressure some consideration must be given to the secondary function of the top blast, which in addition to supplying the necessary oxygen, serves as a deflector of the burning gases upon the charge. This impingement is considered a necessary detail of successful operation, in that it favors rapid and efficient heat transfer to the metal throughout the melting process and tends to break up the continuity of the heat flow to the extent that better radiation from the brickwork beyond follows. With too high pressure, however, there is danger of blowing holes through the fire and consequently increased portions of unconsumed oxygen forced into contact with the melting charge favor undue oxidation of the elements. Fortunately a certain amount of oxidation is very desirable and with a properly designed top blast arrangement and its dual function in mind the elimination of the desirable portion of the elements becomes a simple, predetermined matter. A slight turn of the oil valve or a mere change of the lever controlling the overhead blast openings does the trick.

Among the outstanding advantages of oil firing are the uniformity of operation and the ability to produce the desired composition as soon as the iron has attained the proper pouring temperature. Table I shows the record of twenty consecutive heats run without changing the initial charge or the method of firing in any way. This data illustrates the possibilities of oil firing, as well as the uniformity of the product. The oil consumption is somewhat high, due to small heats, nevertheless

the figures given offer a saving for this locality of at least twenty percent over the fuel cost of hand firing. The best oil and melting rates, as well as the most uniform results, are obtained from heats approaching the normal capacity of the furnace. Weekly averages of 55 gallons per ton are readily obtained from 10 to 11 for charges. If the furnace is taxed beyond capacity the oil consumption raises again, a condition resulting from the abnormal increase of time required to superheat the charge, as well as the necessity to maintain a high roof over the hearth in order to accommodate the bulky charge. A rather long, narrow hearth is very desirable for quick results. This construction favors heat absorption by the charge and if the top blast is properly reduced during pouring time, the molten metal need not be endangered from excess oxidation as the result of a shallow bath. Providing the initial charge, however small, is properly distributed, prompt melting and skimming, quick superheating and a corresponding decrease of pouring time will readily offset the higher oxidation rate afforded by a shallow bath.

Two Heats Preferred

The question of one large or two small heats per day has received every consideration and proven in favor of two small heats, especially from the standpoint of molders daily production. Actual trials indicate that large heats offer no economy as far as fuel consumption and other melting cost, including furnace operating and repair labor and refractory materials are concerned. Increased production and decreased foundry space reduce fixed charges and overhead expense beyond any possible increase of indirect foundry labor costs. Better production is brought about by the molders ability to increase his output without overtaxing his pouring capacity. Furthermore, the smaller floor spaces permit crowding the molders closer to the furnace, a desirable factor, especially in view of the light work, since it eliminates rehandling the molten metal and consequently the necessity of additional superheating.

In operating on a two heat schedule, the nine hour day is divided by the noon hour into two separate and complete periods of four and one-half hours each. Of each period nearly four

hours are devoted to molding; the remaining half hour to pouring, dumping and the removal of castings from the sand. Owing to efficient furnace control this schedule is now followed with almost clockwork precision. All overtime is eliminated, with the exception of sand cutting, and the necessary furnace repairs at each week end.

Loss And Gain Of The Elements

In considering the behavior of the elements during melting, little attention need be paid to the sulphur content of the charge. The increase is invariably small and seldom in excess of ten per cent of the original content. Unless off-sulphur pig iron is intentionally used to balance the manganese-sulphur ratio, the hard iron always analyzes below .05 per cent sulphur.

Phosphorus is easily controlled; its gain is in proportion to the melting loss and a fairly constant figure is readily obtained through suitable pig iron selection. As a safeguard against annealing troubles, this element is seldom allowed to run above 0.18 per cent. The extra margin of fluidity that a higher phosphorus content might impart to the molten metal is too insignificant to jeopardize the product to an extent that cannot be predetermined.

The oxidation of silicon and manganese goes hand in hand and takes place mostly while the charge is melting. The nature and amount of slag indicate whether the elimination of these elements has been moderate or excessive. With comparatively low losses corresponding to the figures submitted in Table I the slag proves viscous and amounts to about one hundred and thirty-five pounds per ton of metal charged. With higher silicon and manganese losses the slag appears more fluid and increases in weight at the approximate rate of ten pounds per ton for every ten points additional silicon loss. This condition, however, is somewhat influenced by the carbon loss, which has an indirect, yet noticeable effect upon the erosion of the sidewalls below the metal line and consequently upon the basicity and bulk of the slag. The extent of the silicon and manganese loss depends mainly upon the excess of total or top air, the position of the wind bung, efficient distribution of the charge and its initial content. Excessive oxidation of these elements, as a direct

result of the bessemerizing effect of too high top air pressure, is not desirable, in spite of the very attractive oil rates obtained. While a considerable amount of internal heat is thus generated and a higher bath temperature obtained, on the other hand serious carbon losses and unruly furnace conditions result and foundry troubles follow.

The amount of silicon and manganese eliminated in this practice depends upon the composition of the pig iron in stock, as well as the supply of available sprue. The total remelt seldom runs in excess of forty per cent of the charge in spite of the light to medium class of work. No attempt has been made to establish oxidation rates below the figures given in Table I, as this would lead to abnormal sulphur-manganese ratios unless the usual sprue shortage is offset by high sulphur-low silicon and manganese pig iron or large amounts of malleable scrap. The latter method would undoubtedly lower the metal cost and create a saving over the increased melting costs, but since quality and uniformity are considered the outstanding factors in present day practice, is it policy to over-expose the product to accumulative troubles, resulting from guesswork or detrimental impurities?

Carbon The Unruly Element

Carbon is the most unruly element to contend with and has proven the main source of grief during the experimental stage of oil firing. The primary cause of carbon difficulties results from faulty application of the top blast which is usually delivered in insufficient quantities at too high pressure. Malleable scrap or steel of uniform composition is used to reduce the initial carbon content of the charge. When no sprue, no reliable malleable scrap or no low manganese or high sulphur pig iron is available the preference goes to steel and additional normal pig iron in conjunction with an intentionally high oxidation rate. The idea is to normalize the sulphur-manganese ratio through elimination of the excess manganese by oxidation. The higher metal cost thus created is partially or wholly offset by a better fuel rate, incidentally followed by faster melting.

The elimination of silicon is not necessarily associated with a proportionate carbon loss. Under certain conditions either

element may yield readily while the other holds tenaciously. During the first heat following the complete renewal of the furnace bottom, for instance, the carbon usually lowers abnormally, whereas the silicon and manganese persist. This tendency accounts for the higher silicon-lower carbon content of heat number 308 shown in Table I. On the other hand, heats charged with the usual silicon and carbon percentages have been known to loose as high as eighty points silicon and only thirty-five points carbon. Similar cases, encountered during experiments, indicate that, if the silicon content is initially low to the extent that an under-balanced carbon-silicon ratio must follow. the latter element proves weaker than usual and yields abnormally, thereby favoring the carbon. The extent of the carbon loss is usually indicated by the granular to flaky structure of the final test plug, also by the color and behavior of the molten metal, the appearance of the slag and other symptoms. Unlike silicon and manganese, the required elimination of which is nearly complete by the time the metal is under slag, carbon continues to yield until the metal has attained the desired pouring temperature, permitting a reducing atmosphere through radical reduction of the top blast.

The most prolific source of carbon troubles is too high top air pressure. Other troubles are complex due to the influence of numerous factors. Undue carbon elimination may result from excess air, as well as prolonged firing, brought about by poor furnace control; also by an improperly balanced top and bottom air ratio or a desire to run abnormally large heats, requiring prolonged exposure while super-heating the molten

TABLE 2.
Silicon and Carbon variations during pouring time

Heat No.	First Metal Poured		Last Metal Poured	
	Per Cent Silicon	Per Cent Carbon	Per Cent Silicon	Per Cent Carbon
372.....	.96	2.39	.96	2.36
374.....	.93	2.48	.91	2.45
376.....	.91	2.39	.93	2.32
378.....	.92	2.56	.88	2.47
380.....	.86	2.52	.87	2.46
382.....	.95	2.49	.97	2.46
384.....	.96	2.46	.94	2.42
386.....	.99	2.60	.98	2.45

In case of heat No. 386 the top blast was not reduced until the heat was half tapped.

metal previous to pouring. The data of Table 2 gives a fair idea as to the protection afforded by a reduced atmosphere maintained over the bath during pouring; the volume of air admitted at this time, even though far below theoretical requirements, being sufficient to maintain a uniform metal temperature. The manipulation of the top blast at pouring time is governed by the carbon content and inasmuch as the lower carbon range requires additional superheating, naturally the top blast must be admitted in sufficient quantities to maintain the desired pouring temperature.

Results Predetermined

In connection with oxidation it can be stated that the desired hard iron analysis is usually attained through predeter-

TABLE 3.

Sample Marked	Ult. Strength lbs. per sq. in.	Elongation in 2 inches per cent
11- 1-252-2	57520	24.50
11- 2-257-1	56550	28.00
11- 3-261-1	55860	27.00
11- 4-264-2	56140	27.00
11- 6-268-2	56610	22.00
11- 7-271-1	56900	18.00
11- 8-277-1	54910	22.50
11- 9-281-1	54220	23.00
11-10-284-2	54470	17.00
11-13-288-2	54505	19.50
11-14-292-2	54990	22.50
11-15-297-1	53690	27.50
11-16-300-2	56242	22.50
11-17-304-2	55740	23.50
11-18-307-1	53822	21.50
11-20-310-2	56240	23.50
11-21-313-1	55780	27.00
11-22-316-2	54550	21.50
11-23-321-1	57010	27.00
11-24-325-1	55150	27.00
11-25-329-1	52030	16.50
11-27-330-2	55810	26.50
11-28-335-1	53850	21.50
11-29-340-2	55330	25.00
Total Average	55330	23.40

Average of No. 2 furnace bars (samples marked 2).
Ult. Strength, 55679 lbs. Elongation in 2 inches 22.92 per cent.
Average of No. 1 furnace bars (samples marked 1).
Ult. Strength, 54981 lbs. Elongation in 2 inch 23.87 per cent.

mined elimination of the excess impurities and that the physical properties are not noticeably affected by the extent of oxidation, as illustrated in Table 3. This monthly report gives the tensile properties of an equal number of daily tests obtained from two oil fired furnaces operated in a different manner. The chemical data on some of these tests is shown in Table I under corresponding dates and numbers. The final composition runs uniform for both furnaces, although the silicon loss averaged fifty-six points for the bars obtained from number one furnace as against thirty-three points in the case of number two furnace. Number one furnace was charged with 54 percent pig iron, 6 percent steel and 40 percent sprue; while number two contained 50 percent pig iron, 10 percent malleable scrap and 40 percent sprue. The favorable comparison of the average results proves that, irrespective of the initial charge, the manner of operation can be adjusted to bring about ultimate uniformity.

Repairs And Refractories

One of the important factors worthy of consideration in studying the operation of the air furnace is the serviceability of fire brick used for sidewall replacement and bung construction.

The saving of refractory material, although varying with oxidation and furnace control, is a recognized feature in favor of oil firing and its importance can be further emphasized by giving due consideration to the correspondingly substantial decrease of repair labor. Actual results covering a five months' run are shown in Table 4.

The combustion chamber, including the bungs covering same, seldom requires attention during repair time, in fact the life of this part of the furnace, with the exception of the extreme ends of the combustion chamber and the bottom directly below the blow bung, exceeds one year of continued service.

While the furnace is repaired weekly, the nine inch inner lining of the angle walls, or that portion of the sidewalls extending from the end of the combustion chamber towards the middle of the hearth for a length of about ten feet, serves a three weeks run of two daily heats. The remaining stretch

TABLE 4.

FURNACE REPAIR AND FUEL DATA

228 HEATS, AVERAGING 8.5 TONS—TOTAL MELT 1935 TONS

	Total for Period	Per Ton
Repair labor, including hauling brick and material, building bungs, etc.	1030 Hours	32 Minutes
Roof Repairs:		
13 inch Bungs	34	
13 inch Bung Brick	1054	
18 inch Bungs	54	
9 inch Bung Brick (Straight and arch)	3890	
Bung Brick (9 inch equivalent)		3.0 Brick
Sidewalls: Including combustion chamber, hearth, neck and bridgewalls.		
9 inch Straight Brick	5790	
9 inch Wedge Brick	250	
9 inch Arch Brick	370	
Soaps	330	
Splits	540	
Sidewall brick per ton		3.8 Brick
Tapping Blocks	44	
Bales of Straw	22	
Fireclay	39200 lbs.	20.0 pounds
Silica Sand	51700 lbs.	26.7 pounds
Fuel Oil	119800 gals.	61.9 gals.

of the sidewalls up to the rear bridge wall is batted, wherever needed, during repair time; the bats recovered from the angle walls and the crushed salvage of the bungs being used for this purpose. By resorting to this manner of maintenance the original lining of this portion of the sidewalls serves a seven to ten weeks run.

The bottom of the furnace is taken up once a week and renewed with fresh additions of washed silica sand. The brick bottom has been tried out during the course of experiments but its adoption was abandoned for various reasons. While the saving of labor and material is unquestionably in favor of the brick bottom, especially where large heats are the rule, it was found that these bottoms became ragged within a short time and the formation of pools of molten metal not only proved a source of additional fuel requirements but the uniformity of the successive heats became impaired to a noticeable extent, varying, of course, with the condition of the bottom and the size of the heats.

The life of the bungs is perhaps the most interesting feature in connection with the function of refractory materials. Figs.

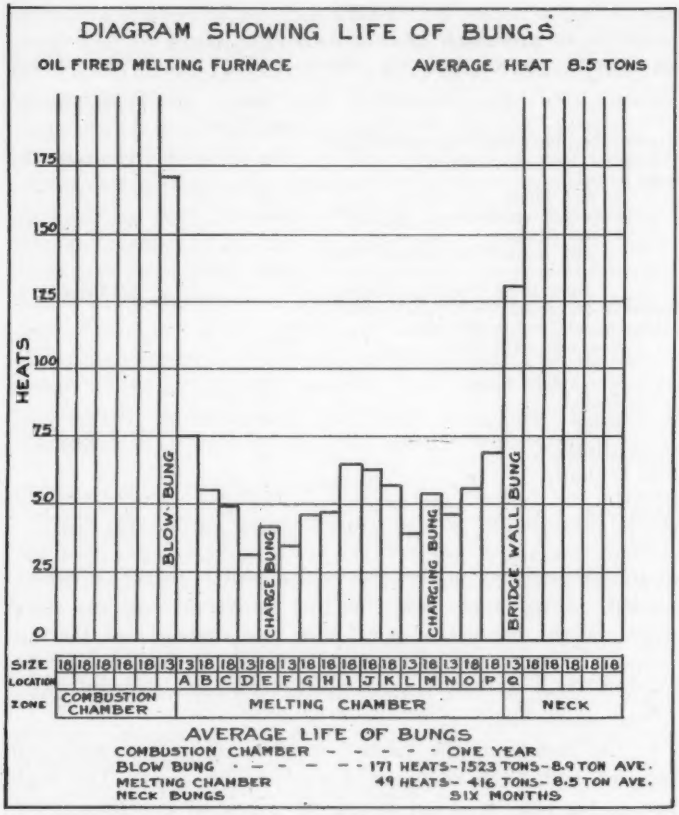
DIAGRAM SHOWING LIFE OF BUNGS
OIL FIRED MELTING FURNACE
AVERAGE HEAT 8.5 TONS
HEATS
175
150
125
100
75
50
25
0
BLOW BUNG
CHARGE BUNG
CHARGING BUNG
BRIDGE WALL BUNG
SIZE 16 16 16 16 16 13 13 18 18 13 18 13 16 16 18 18 13 16 13 18 18 13 16 16 16 16 16
LOCATION A B C D E F G H I J K L M N O P Q
ZONE COMBUSTION CHAMBER
MELTING CHAMBER
NECK
AVERAGE LIFE OF BUNGS
COMBUSTION CHAMBER - - - - - ONE YEAR
BLOW BUNG · — — — — 171 HEATS-1523 TONS-8.9 TON AVE.
MELTING CHAMBER 49 HEATS- 416 TONS- 8.5 TON AVE.
NECK BUNGS SIX MONTHS

FIG. 4—DIAGRAM SHOWING LIFE OF BUNGS

4 and 5 gives the graphic and tabulated results as obtained from experiments with over two hundred bungs on which individual records were kept. These service tests, covering a two year period were carried on under various furnace conditions and the brick used for the purpose included different brands obtained from five firebrick producers. While it is not intended to enter into a lengthy description of results, it might prove of interest to bring out a number of definite conclusions drawn therefrom:

LIFE OF BUNGS ON 13 TON OIL FIRED FURNACE

2 SMALL HEATS PER DAY - AVE 8.5 TONS. 76 BUNGS USED. AVE LIFE 49 HEATS. AVE LIFE 416 TONS				
LOCATION	SIZE	TOTAL BUNGS USED	AVE. LIFE OF BUNG IN HEATS	AVE. LIFE OF BUNG IN TONS
A	13"	2	75	622
B	18"	4	55	488
C	18"	5	49	441
D	13"	8	32	280
E	18"	5	42	363
F	13"	8	35	303
G	18"	5	46	384
H	18"	5	47	406
I	18"	3	65	534
J	18"	3	63	534
K	18"	4	57	466
L	13"	6	39	330
M	18"	5	54	462
N	13"	5	46	390
O	18"	4	56	461
P	18"	3	69	601
Q	13"	1	131	1043

2 MEDIUM HEATS PER DAY - AVE. 10.8 TONS. 74 BUNGS USED. AVE LIFE 41 HEATS. AVE LIFE 444 TONS				
LOCATION	SIZE	TOTAL BUNGS USED	AVE. LIFE OF BUNG IN HEATS	AVE. LIFE OF BUNG IN TONS
A	13"	3	50	570
B	18"	4	47	493
C	18"	4	41	444
D	13"	7	26	273
E	18"	4	32	346
F	13"	7	29	307
G	13"	3	43	434
G.G.	18"	4	44	479
H	13"	4	44	466
I	18"	4	53	573
J	13"	4	42	446
K	13"	5	36	379
L	13"	6	33	356
M	18"	4	40	421
N	13"	5	35	375
O	18"	3	57	607
P	18"	2	74	871
Q	13"	1	115	1219

ONE LARGE HEAT PER DAY - AVE 13.7 TONS. 80 BUNGS USED. AVE LIFE 31 HEATS. AVE LIFE 426 TONS				
LOCATION	SIZE	TOTAL BUNGS USED	AVE. LIFE OF BUNG IN HEATS	AVE. LIFE OF BUNG IN TONS
A	13"	3	44	570
B	18"	5	36	495
C	18"	5	33	445
D	13"	7	21	291
E	18"	7	25	341
F	13"	8	20	272
G	18"	5	29	400
H	18"	4	40	565
I	18"	4	36	514
J	18"	4	40	534
K	18"	5	35	456
L	13"	7	21	288
M	18"	4	36	490
N	13"	4	24	343
O	18"	4	41	549
P	18"	3	46	667
Q	13"	1	116	1620

FIG. 5—LIFE OF BUNGS ON 13-TON OIL FIRED FURNACE

A saving of not less than fifteen per cent of the initial cost of the brick is brought about by substituting the undisturbed 13-inch bungs with 18-inch bungs. Taking for granted that the 18-inch bungs last fully as long as the 13-inch bungs and knowing that forty-three 13-inch bung brick have an area equal to the seventy-two 9-inch straight and arch brick required to build one 18-inch bung, a simple multiplication of the number of the brick by their respective price will prove this statement.

In selecting brick for bung purposes the texture is carefully examined and the density and porosity, as well as the size of the particles and the degree of burn are closely observed

and given primary consideration. A comparison of numerous fractures with available data on individual service tests points to an apparent relation between actual service, porosity and spalling action. This rule, however, is not always consistent and it is found, especially in case of the denser, finer grained brick, that initial spalling is not a sure indication of decreased serviceability. Extremely porous brick are not desired, as a rule they spall readily, lack strength and afford poor resistance to the abuse of frequent handling.

Mechanical strength, brought about by increased density and hardness, is the essential sought in the 13-inch brick used for the bungs on each side of the charging openings. These bungs are severely abused through contact with the descending charge and the leveling rods and in their case mechanical strength overshadows the significance of other qualities. As for the 18-inch bungs, if the texture indicates that extreme density and excessive porosity have been avoided by blending various portions of small to medium grained calcined and flint material with just enough bond clay of sufficient coarseness to give uniform cohesion and providing the initial clays possess a suitable decree of refractoriness one is almost insured of excellent service. Such brick, in spite of apparent tendency towards density, are quite neutral to expansion and contraction; the resistance to spalling, not withstanding the general opinion to the contrary, is much greater than in the very coarse, open and porous brick, and the mechanical strength seems sufficient to withstand the abuse of handling. The degree of burn deserves some consideration. A medium burned brick is most suitable for the less disturbed bungs, altho a soft burned brick of suitable texture proves equally resistent to spalling but its service is at times impaired by the abuse of frequent handling.

The chemical composition of fire brick for bung purposes needs no comment; this feature, as well as the expansion and contraction, seems well taken care of by the firebrick producer. This statement is corroborated in Fig. 5 showing the life of numerous bungs. A comparison of the tonnage served in the

small, medium and large heats fails to indicate that more frequent cooling has a marked effect on the service of the bungs.

A lower priced brick is suitable for sidewall replacements. The main requirements are sufficient hardness and density to withstand the cutting action of the moving gases and the erosion below the metal line in a uniform manner.

The bung frame used for both 13 and 18-inch bungs is shown in Fig. 3. These frames, made of malleable iron, are easily assembled and last indefinitely; they are strong and efficient and offer several advantages over the commonly used "T" and "I" bung frames. Undoubtedly the most important feature of the frame is that it leaves fully eighty-five per cent of the top surface of the brick work uncovered. This feature enables more uniform heat radiation through the brick work, thus insuring increased service of the bung. Another desirable point is that the bungs are readily stacked in tiers during repair time, without resultant damage to the brickwork.

Influence Of Human Nature

In connection with the operation of the oil fired furnace it can be stated that the importance of a great factor, human nature, is often disregarded. This condition exists in spite of abundant proof that the human factor has a tendency to curb the possibilities of an ideal fuel to the extent that uniformity and other essentials unnecessarily suffer. Costly experience, resulting from over-confidence, lack of knowledge or subsequent neglect, has proven in many instances that the principles of metallurgy, chemistry and combustion cannot be minimized in initial installation, nor disregarded in subsequent furnace adjustments necessitated from time to time by radical changes in the size of the heats or the contents of the charge.

Usually the furnace attendant is infused with a number of traditional ideas, inherited from hand firing practice, and while these ideas are obviously detrimental when applied to a constant fuel, it is nevertheless no small task to convince the furnace man of the obsoleteness of his doctrine. Thus, the most prolific source of fuel waste and lack of uniformity is brought about by the general tendency to produce a flame that puffs

through the bungs and cracks, and in spite of discomfortable surroundings, as a result of excessive radiation and the side pressure through skimming doors, the furnace tender remains skeptical, until the metallurgist has demonstrated that a lean flame actually does the work and does it fast. Again the initiate may become so enthusiastically convinced that his previous assumption involved a waste of fuel and time and more important to him, a waste of physical energy; that he resorts to the other extremity by cutting the fuel supply to the extent that excess oxidation and unruly furnace conditions must follow. Either method is in direct violation of the laws of combustion. The latter method is usually followed by a tempting oil rate, especially where high pressures prevail, but can one resort to it and escape the inevitable consequence?

In determining the proper density of the furnace flame, a faint outline of the opposite sidewall as viewed through the back skimming door or similarly a fixed impression of the appearance of the bung above the bridgewall as seen through the stack opening serves as a guide. However, since density does not denote effectiveness unless the flame has a suitable velocity; the all important problem—maximum heat absorption by the charge—must be solved through consideration of the interdependent conditions that impart to the flame the velocity that yields the best obtainable thermal efficiency. The wide range of straight line to circular flow of the flame, important as it is, means little to the furnace man. Again, therefore, the human element may interfere during repair time, by making a thoughtless furnace change, apparently of minor importance, thereby changing velocity and thermal efficiency.

It is a common belief that no two air furnaces of identical proportions can be made to operate alike, but in line with the foregoing and in view of the fact that most of the usual attention is centered on heat generation and comparatively little on heat absorption, is it after all a mystery? Does it not point to the complexity of delicate conditions existing within a crude melting apparatus?

In connection with the foregoing it can be stated that the use of fuel oil offers a logical solution for further improvement

along the lines of uniformity and fuel consumption. It is believed that a simple and practical operation schedule, with an additional repair schedule, in preference to haphazard firing and furnace maintenance would promote uniformity to a constant factor. These two schedules, together with the necessary modifications, covering a wide range of oxidation and small to large heats, will be based upon the results of extensive and varied experiments with large and small heats. The idea is to curb unsound practice by using a constant fuel rate with a definite air volume, in connection with a predetermined melting period for any given heat.

Conclusions

The writer has tried to bring out the following outstanding features in connection with the melting process of malleable iron with oil as fuel:

First; The absolute advantage of proper combustion and heat control, enabling consistently uniform molten metal.

Second; Control of charge and elements, through desired oxidation, to insure uniformity of product.

Third; Virtual control of element of time, thereby increasing production to a marked extent and efficiency.

Fourth; Decided economy of repair labor and costly materials in furnace maintenance.

Fifth; Elimination to a greater extent of the human element in furnace operation.

A number of other important features are not covered in this article such as elimination of excess labor in furnace operation, handling of raw and waste materials, a marked decrease of foundry scrap and other items of a more or less degree of value.

As indicated in the beginning, this paper has been written from facts and results obtained during a number of years of practical experience and laboratory research work.

The writer is aware that some statements are made which are not in accordance with general opinions, therefore written criticism, as well as discussion is earnestly desired to promote

a better understanding and to correct possible erroneous statements.

It is hoped that some statements at least will be of interest and possibly of advantage to the industry.

Discussion—Application of Fuel Oil to Malleable Air Furnaces

G. W. Neely.—Did I understand the author of the paper to state that the combustion of the oil in the oil chamber had a tendency to make a carbon deposit in the combustion chamber?

A. Van Landschoot.—The carbon deposit in the combustion chamber is caused by the burning of less than the theoretical amount of air necessary to produce the first product of combustion. In that case free carbon floats along through the combustion chamber and deposits against the roof of the side walls of the combustion chamber.

G. W. Neely.—Do you have a slow moving sort of a smokey or reducing flame over the bath of the metal, or do you have a sharp oxidizing flame?

A. Van Landschoot.—The flame as observed through the opening is rather lean and bright. It moves at a fairly high speed and it does not have the leaping and bounding motion that a flame might have, nor it has not the straight line flow. The flame itself is very lean in fact, through the doors you can see the opposite side of the bridge wall opening. That is almost a sure indication that the flame is not only lean, but that the temperature is pretty well up.

G. W. Neely.—The reason I asked that question is that we have recently installed oil burners in three air furnaces for the melting of chilled iron for rolls. On the recommendation of the people who installed the furnace, we went on a sort of reducing flame, with the idea that a reducing flame would act quicker in the melting of the metal. Since then, we have changed the design of our burner so as to get a sharp white

flame completely filling the chamber immediately above the bridge wall. We took this stand due to the fact of our experience in coal firing furnaces, having three furnaces on hand firing and one on stoker firing. The three furnaces on hand firing, we found the flame visible at the rear of the furnace where it entered the flue up in the stack. In the stoker furnace we had no flame, you might say, at the rear of the furnace, the flame being a sharp white flame immediately above the bridge wall. In going on oil and trying to reproduce the flame of the hand fire furnace, we used a considerable amount of oil in melting, and our time was greatly extended. Since going on the propostion of having a white hot flame immediately above the bridge wall, completely filling the cross section of the furnace at that time and allowing the draft of the stacks to pull those hot gases through the furnace, we have materially cut down the amount of fuel. On a 36,000 furnace, melting about 32,000 pounds of metal in a mixture consisting of 70 per cent scrap and 30 per cent pig iron, the scrap totalling up in some cases as high as 12,000 pounds per piece, we have melted our charge at an average of 65 gallons per ton, which I think is conclusive evidence that the hot flame is of more material benefit in melting, as your records show you have melted about 63 gallons per ton, but the size of your scrap is considerably below the size of our scrap or you may be melting scrap consisting of a 50-50 or 60-40 mix, and scrap weighing 100 pounds. We are melting a piece weighing 12,000 pounds, and yet we are getting results with the hot flame of approximately 65 gallons per ton.

A. Van Landschoot.—In this connection I might state that the rate per hour applies to a certain method. This rate can easily be drawn down to a 55 or even a lower rate per hour by bessemerizing the charge. We have hotter flame than when the charge is oxidized, oxidized to the extent that more pig iron must be emptied into the charge or else we should resort to other measures. Now this practice is not desirable in our case.

G. W. Neely.—The question has been brought up as to the number of hours of melting. As I understand, in your

malleable furnace, you have to work up to a white metal. In our furnace conditions, we light a furnace at 7 o'clock in the morning for a 36,000-pound heat, and tap that heat at any time from 2 o'clock to 4 o'clock, depending on how long it takes the metallurgist to get sufficient chill on his test bar for the roll. We have averaged, in good results, 135 gallons per hour, or as I stated before, 65 gallons per ton. Our best record has been down to 53.5 gallons per ton on a heat of 36,000. On that heat we started at 7 o'clock in the morning and had the heat out by around half past two, which I believe is good melting, when you consider that in that heat there was one piece of 11,000 pounds weight, two pieces of 7000 pounds weight and the balance made up of smaller pieces, the smallest of which weighed about 600 pounds, the mix consisting of 70 per cent scrap and 30 per cent pig iron.

S. Mackay.—In asking me to present a written discussion of this paper, it is rather putting the student in the position of criticizing or rather measuring the attainments of his teacher, because our company is greatly indebted to the Iowa Malleable Iron Co. and Mr. Landschoot personally for the assistance he has given us in working out our problems, and we have the same troubles and bewilderment that he went through in his early days. The time we have been melting with oil successfully is not a couple of years but a much shorter time. Our troubles in the beginning were the ordinary troubles so many people have in controlling oxidation. We know that an oxidizing flame will oxidize but we did not seem to know how to apply that to our furnace until we were shown the way to Mr. Landschoot's demonstration. The value of his work has been that he took his own medicine, and it is good medicine, and that gave us the courage to follow. One or two things in his paper seem worth commenting on. Perhaps they do not need emphasizing, but I am going to speak of them; a low suction and the large opening that he speaks of makes me think that, whether intentionally or by accident he has followed what I have been told is the very latest practice in designing open-hearth furnaces, that is analyzing the dimensions of the furnace on the hydraulic plan. He brings up the point

that it is not necessary for your furnace to be full and bursting with flame, that no flame at all need crowd itself out of the furnace, but rather a continuous and more or less gentle flow through, and from these hot gases flowing through according to natural laws, more heat is absorbed and less refractories destroyed than under any other conditions, and we have reason to know what a forced flame will do to refractories. With a forced flame we have not been able to save anything of refractories as compared with our cold melt, but others have been able to save remarkable refractory consumption by following closely his guidance in this matter. He emphasizes also the double stage burning, many of us know that carbon in burning does not burn all at once, but I wonder how many of us have realized just what that meant in the furnace and just what the importance of the top blast was in connection with bringing about this reverberatory effect of this double stage burning? There again a person can get into trouble by not realizing the importance of his top blast, either by not having sufficient or by having too much and actually blowing oxidizing air right through his oil flame down into his metal and burning out the very elements he is expecting to conserve, thereby increasing greatly the cost of his melt. Mr. Landschoot has done two things, he has demonstrated how oil should be burned and he has shared with us really the same troubles and had them to overcome to get the results from his work and I want to express at this time my appreciation of the immense value of his work and that of the organization with which he is connected.

Stanley Flagg.—I would like to ask if those who are now using oil are really satisfied with it as against the use of a good grade of gas coal? It has always been a question in my mind as to the actual economy, because those plants I have known that used oil had an unfortunate experience, and I would like to know if Mr. Landschoot feels really confident in the economy of the use of oil outside of the improvement he he should get in the metal.

A. Van Landschoot.—The economy of burning oil as compared with gas coal—I could not answer that question.

G. W. Neely.—We have tried to figure out whether we are ahead of the game on coal or oil. According to the office records, they tell us that if we can reduce the cost or reduce the amount of oil used to 55 gallons per ton melt, we will make money on the use of oil, but, of course, being in the shop, we do not believe those records, because we look around and we see that on each furnace we cut down one helper. We are now operating three furnaces with three men, for which formerly we used six men, plus two coal passers. That meant that on the three furnaces we cut down five men and the wages of five men amount to quite considerable in a day. At the same time we have cut down the unloading of the coal in our plant. We unload by locomotive crane into the yard; we reload again into our own flat cars and transfer and unload again into the furnace pits. There in itself, is a considerable waste of money in the handling of coal. As far as oil is concerned, we hook it up and turn on the compressed air from the compressor and let her go. Now when you look at those things, it does not look as if coal is cheaper than fuel oil. On the other hand, in the pumping of our fuel oil, we have electrical energy, we have the wear and tear on machinery, we have the piping to keep absolutely free of leaks, but that only requires the service of one competent man to go over the system or look after the system each day. We have cut the cost of scrap or the amount of scrap since going on fuel oil. but we do not choose to lay that to the use of fuel oil any more than to the fact that the weather conditions and the product that we had to make were easier for the metallurgists to handle his product; so as I say, from the point of view of the shop, we firmly believe that we are making money on fuel oil, but the office records point otherwise.

Stanley Flagg.—I am familiar with one case where oil was put in the shop and they said they saved a lot of money, but took the oil out, and that is the reason I cannot see where oil comes in if you can get a first-class coal at a reasonable price delivered, and I have never been able to grapple with this oil question. If your oil goes to $55.00 a ton, you are up against a stiff proposition.

A. Van Landschoot.—In further reference to the comparison

between the cost of fuel, I might say that in our case there is a saving of at least 25 per cent over the cost of coal in favor of oil, in spite of the 63 gallons a ton rate. In the case of coal, our freight rate exceeds $5.00 per ton. In the case of oil, our freight rate is less than one-half the cost of the oil, and when we compare an oil cost of 4 cents a gallon with a coal cost of $10.00 a ton, we find that the saving is not less than 25 per cent of the fuel cost in favor of oil.

S. Mackay.—It is the usual thing in comparing coal and oil to consider whether the fuel cost is greater and then try to balance that up by showing where we save a man here and a man there. That is all right; we can pretty well balance it up in that way, but I think there are some items on the side of the scale which favor oil that are pretty hard to put any value on and yet which have a very distinct value. For instance, many of us, all of us, I guess, can hardly tell how many of our men will be in tomorrow morning, but tonight we must determine how much of a charge we are going to put in. That is true in our case and in the case of a good many foundries around us. With oil it is possible to see how many men are in and how hard they are working and charge our furnace and make our heat. That is a distinct economy and then to have the heat come on time, uniformly on time, uniformly hot, and acceptable metal to molders not only decreases shop scrap but shop dissatisfaction, and at a time when your men are the dictators in the shop, that is worth a great many cents. If the men come to your gate and say "can you give me a job." Why, I thought you were over at so and so?" "Yes, but we have not had the metal on time for a week and a fellow can't make any money." It's a whole lot to have men know that day after day they are going to have hot metal on time. There are other factors undoubtedly which users of oil here could bring out that will offset some few cents in fuel value. Those things appeal to us, and I think we are pretty well sold on the use of oil, especially as we are not worrying as much as we did about the uncertainty of getting it.

P. C. De Bryne.—I agree very much with the gentleman from Pittsburgh, being a shop man, that there is a great saving

in the use of oil over coal. However, I would like to hear from our president, Mr. Fontleroy. He is in a better position to state it than I am.

Mr. Fontleroy.—Our records show that there is an actual saving, taking all accounts into effect, that you do not simply want a balance in the cost of your fuel oil against the cost of your coal, there are lots of other contributing factors; the saving of labor, the saving in your cost of fire brick. The fire brick in our case, the cost of it makes the cost of the fuel oil less than the cost of burning coal. I think there is one additional factor that should be taken into account and that is that the work in the malleable foundry is hard hot dirty work; you cannot get away from it and the firing of the melting furnace, where you have to shovel in five shovelfuls of coal about every two minutes and rake over your fire is just about the stiffest work you have. With oil, it goes in at a certain number of gallons per hour and the condition of the melter's disposition has no effect whatsoever on the rate of oil going into that furnace.

G. W. Neely.—I would like to add a few remarks to those of the gentlemen who just spoke. In the melting of large scrap weighing 9000 pounds on an average, it is necessary to get in there with an inch and a quarter steel bar eleven feet long and peel that off periodically. This has to be done whether you are melting by fuel oil or by coal. Now it has been my experience in the melting of these furnaces using coal, that it required hard tugging and pulling by both the furnace man and his helper. We fired our furnaces every ten minutes. Now, as I say, we have cut off one or these men; we are now working that same furnace, melting the same material with one man, and he works a whole lot easier than he did with the aid of a helper. On the other hand, the brick people came around and said, "you are going on fuel oil, therefore, you will need a special brick, one that will withstand fuel oil and we have it." We have not changed our brick. Before we went on the fuel oil, we would have to throw a patch in the low roof, immediately above the bridge wall about every fifty heats. When you begin to patch a roof, you begin to chase up trouble. At present, running on fuel oil, I have one furnace that I repaired or

rebuilt the low roof after 72 heats; the other furnace was rebuilt after 73 heats; the third furnace is now on its eighty-fourth heat without a patch. We have not patched any of these three roofs; we have rebuilt the entire roof; this was because, in the distribution of the flame, coming from your coal-fired furnace, your flame is thrown up against your roof, and there you have your brick burning out both by intense heat and by erosion. With the use of oil we fire our fuel directly along that roof and it burns out uniformly. We have a competitor of ours who is averaging 55 heats and calls it good on a low roof; going on his assumption that he thinks that he is getting good results with fuel oil, we are getting extra fine results with 84 or 85 heats and still going.

Chairman H. A. Schwartz.—Is there anyone present who wishes to say something on this powdered coal question?

E. E. Griest.—I do not know just what the gentleman wants to know, but we have two foundries equipped for burning pulverized coal, and have had considerable experience with it. We get the same regularity of heats these gentlemen have mentioned in connection with their oil. Further, I rather judge that we get less oxidation loss than the gentlemen mention because we are able to use relatively small amounts of pig iron and still not be short in the amount of carbon. In other words, at the present time, at one of the foundries, we are running about 30 per cent malleable scrap and our carbon is really running higher than I would like to see it running, between two sixty and two eighty hard iron, so that if scrap was cheaper, we could use a very much less amount of pig iron. The refractory cost we find depends very largely on the quickness with which the heats are taken off. If you want really quick time, you do it at the expense of the brick work. If you are satisfied to take a reasonable time for your heats, but still get them off within ten or fifteen minutes of the time you set, the refractory cost is considerably less than it is with hand firing.

A Van Landschoot.—With the reference to use of malleable scrap, I might say that we avoid the use of malleable scrap; the saving effected by using malleable scrap is not the difference between the cost of malleable scrap and the cost of pig

iron; the saving is that difference minus the excess oxidation of malleable scrap, the excess fuel required to melt malleable scrap, and the troubles that might occur through the use of malleable scrap. This latter instance cannot be put down in dollars and cents. As far as oxidation is concerned with us, oxidation is not incidental with the process, it is the process; in other words, oxidation is predetermined; we eliminate the desired amount.

Mr. Grisley.—The question I want to ask is this; we melt malleable by hard coal or oil or ordinary coal-fired furnace, but I have never heard where it has been successfully melted by the use of gas. I would like to ask the writer if gas could be worked out?

A. W. Beaman.—As far as gas is concerned, I tried that out several years ago, tried it for about six months and gave it up as a failure.

E. Touceda.—The Fort Pitt Malleable Iron Co. melts with gas when they can get it.

Hardened and Tempered Malleable Castings

By Edwin K. Smith, Racine, Wisconsin

Malleable iron castings have reached their present place in commerce, through certain unique qualities, chief of which has been their malleability, or ductility. Composed of practically pure iron, (ferrite), their softness, resistance to shock, and machinability, have given them an increasingly large field.

Recently there has been considerable demand for medium grade tools, intermediate between the familiar ten cent variety, which breaks so easily, and the highest grade steel hardware, at comparatively high prices.

This demand has brought into the market, some properly labeled tools, and some labeled to mislead the buying public. It is obvious that the best grade of malleable will not make a first class hatchet, as the head will flatten out, and the edge turn over, unless those parts have been in some way hardened. Such a condition brings up this question of hardening malleable. As we had inquiries in regard to the possibility of hardening parts of castings, it seemed worth while to conduct a series of experiments, with a view of determining:

First.—The feasibility of hardening parts of malleable castings.

Second.—The nature of the hardened product.

Third.—Processes best adapted to hardening.

Information on the subject was extremely scarce. Malleable has of course been case hardened, but results have not been very satisfactory, unless the work has been in very expert hands. Even of this process, there has not been much information available. In fact, the average malleable foundryman, when asked for information regarding hardening of malleable, says positively: "Malleable cannot be hardened."

Experiments To Determine Hardness

As a premilinary experiment, a number of malleable bars were heated to various temperatures, and quenched, with the

rather unexpected result that the quenched metal was extremely hard, and in many cases, had a very fine grained gray fracture, greatly resemblying steel. As a practical test, a bar was roughly ground to the shape of a twist drill, then hardened. Successive samples of brass, gray iron, malleable, steel, and hard white iron were drilled with this tool. This last was rather a surprise, as in the past we had been able to drill hard iron only by means of high speed steel.

In order to determine the actual usefulness of hardened malleable under ordinary shop conditions, a number of hammer heads were cast, hardened, finished, and supplied to carpenter shops, shipping rooms, machine shops, and other departments where hard use was certain. Results were surprisingly good—three months of hard service failed to develop flaws in any of the hammers, although a number of handles had to be replaced. It was notable that none of the hammer heads had "mushroomed", as would soft malleable iron, and none had chipped, as would over-hard steel.

Practical tests having shown that malleable cast iron could readily be hardened, and that the hard product had very considerable shock resisting qualities, an attempt was made to determine what methods could best be adapted towards hardening malleable, also what would be some of the difficulties. To this end several hundred samples of various shapes were cast, and hardened, in diverse ways. For close temperature control, a small electric muffle furnace was found ideal, although rather slow in bringing samples to temperature. For quick work, the ordinary blacksmith forge gave excellent results, after a little practice. For instance, one hundred hammer heads were hardened in one hundred minutes, with a loss of only one casting, which was burned.

Warm water was found best for quenching, and quenching cracks were eliminated by dipping the heated hammer head (about 1700 degrees Fahr.) in the water two or three times, with intervals of about one second between the quenchings. Hardness readings on one hundred samples varied from 40 to 55 scleroscope, which is a satisfactory range for this kind of tool. It was surprising that the rather wide range in quenching tem-

peratures made little difference in the hardness of tools. In this connection it is pertinent to state that scleroscope hardness readings on some twenty high grade steel hammers ranged from 40 to 75. No particular attempt was made to arrive at costs, but it seemed probable that hardened malleable could be produced and finished at less cost than steel of similar physical characteristics.

In order to determine as closely as time permitted, the physical and microscopic nature of hardened malleable, a number of standard 5/8-inch test bars were heat treated in various ways, and results recorded. It is of course understood that the experiments tabulated up to this time in no way cover the field of heat treated malleable in its entirety, their purpose being simply to show the possibilities of the methods, and to give sufficient data to enable the metallurgist to prescribe special heat treatment, should he be called upon to produce malleable castings partly, or wholly, hardened. The heat treatment would obviously depend upon usage which the castings would undergo, and cost considerations.

The results shown below were obtained with iron of various compositions, the general hard iron analysis averaging about: Silicon 1.05 per cent, Sulphur .056 per cent, Phosphorus .14 per cent, Manganese .27 per cent, Total Carbon 2.40 per cent.

Data on Test Specimens

Sample 61

Malleable bar, heated to 1980 degrees Fahr, and quickly quenched in cold water. This sample shows in striking way how even a brief heat treatment will change malleable structure. The physical tests gave an ultimate strength of 33354 pounds, elongation 1.0 per cent and hardness 42. Fig. 1 shows black spots partly filled with temper carbon. The white grains are austenite-martensite. Black lines between grains are troostite. Fig. 2 shows the same sample at a higher magnification with large grains of austenite-martensite surrounded by black lines of troostite. Fig. 3 is same as Fig. 2, except with a larger amount of troostite visible. Near the center is a small nodule of temper carbon, surrounded by white, apparently cementite.

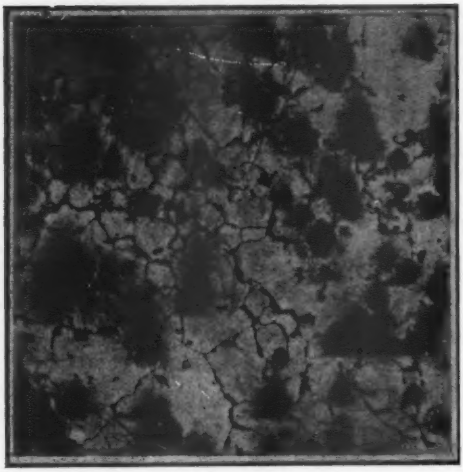

FIG. 1—MICROPHOTOGRAPH OF SAMPLE 61 SHOWS BLACK SPOTS PARTLY FILLED WITH TEMPER CARBON. THE WHITE GRAINS ARE AUSTENITE-MARTENSITE. BLACK LINES BETWEEN GRAINS ARE TROOSTITE. ETCHED WITH NITRIC ACID MAGNIFICATION 100 DIA.

FIG. 2—SAME SPECIMEN AS FIG 1 AT HIGHER MAGNIFICATION. LARGE GRAINS OF AUSTENITE-MARTENSITE ARE SURROUNDED BY BLACK LINES OF TROOSTITE. ETCHED WITH NITRIC ACID MAGNIFICATION 570 DIA.

FIG. 3—SAMPLE 61 SAME AS FIG. 2 EXCEPT WITH LARGER AMOUNT OF TROOSTITE VISIBLE. NEAR CENTER IS SMALL NODULE OF TEMPER CARBON, SURROUNDED BY WHITE, APPARENTLY CEMENTITE. ETCHED, NITRIC ACID. MAGNIFICATION 570 DIA.

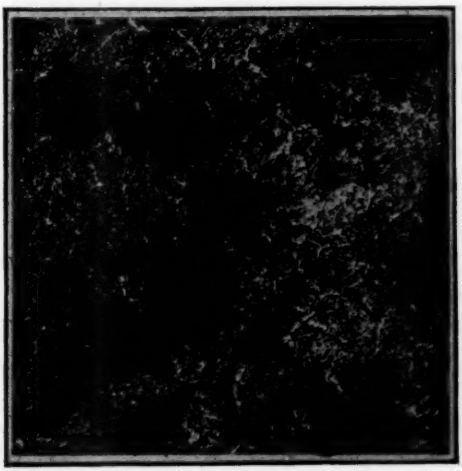

FIG. 4—SAMPLE 615 INDICATES THAT THE DRAWING AT 1200 DEGREES FAHR. HAS MADE A VERY UNIFORM METAL, ALMOST ENTIRELY MARTENSITIC. ETCHED ALCOHOLIC PICRIC ACID. MAGNIFICATION 100 DIA.

The supposition based on the examination of sample 61, was that at 1980 degrees Fahr., the bulk of temper carbon recombined with iron, and that the austenite thus formed was retained by rapid quenching. In order to verify this, analysis was taken of a sample of lightly annealed malleable, which was heated to 1980 degrees Fahr., quenched, and again analyzed, with following results:

	Combined Carbon	Graphitic Carbon	Total Carbon
Original Malleable	.65 per cent (by dif.)	1.63 per cent	2.28 per cent
Quenched at 1980 degrees Fahr.	1.74 per cent (by dif.)	.50 per cent	2.24 per cent

From the above analyses it is obvious that the greater part of temper carbon goes into the combined form, and that at 1980 degrees Fahr., we have a high carbon austenitic steel-like structure.

Sample 615

A malleable bar was heated to 1980 degrees Fahr., and quenched rapidly, then reheated to 1200 degrees Fahr., held at that temperature for three quarters of an hour, and air cooled. The ultimate strength was 69312 pounds, elongation 1.5 per cent and hardness 33. Fig. 4, a microphotograph of sample 615, indicates that the drawing at 1200 degrees Fahr., has made a very uniform metal, almost entirely martensitic. Fig. 5 the same sample but etched with sodium picrate, shows faint black lines of cementite between crystal grains. Sample 615 in Fig. 6 etched with nitric acid and at a magnification of 570 diameters shows martensite in crystal grains, surrounded by cementite. Fig. 7 is the same sample as Fig. 6, except that sodium picrate was used in etching, to darken the cementite.

Sample 628

A malleable bar was heated to 1670 degrees Fahr., and quenched. The ultimate strength was 33170 pounds, elongation 1.5 percent and hardness 60. Fig. 8 shows a close grained structure, greatly resembling hard steel. Sample 628 in Fig. 9 the same as Fig. 8, but higher of magnification shows a structure which appears to be mainly sorbitic-pearlite, with martensite.

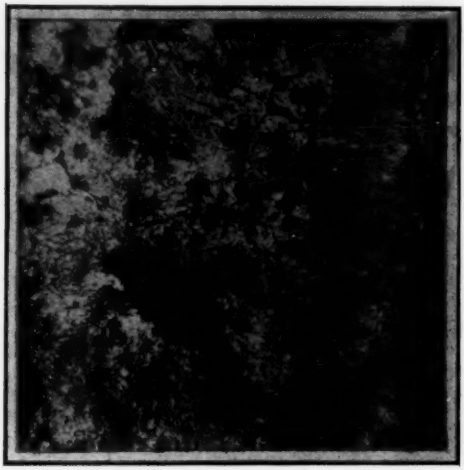

FIG. 5—SAMPLE 615. SAME AS FIG. 4 BUT ETCHED WITH SODIUM PICRATE, SHOWING FAINT BLACK LINES OF CEMENTITE BETWEEN CRYSTAL GRAINS. MAGNIFICATION 250 DIA.

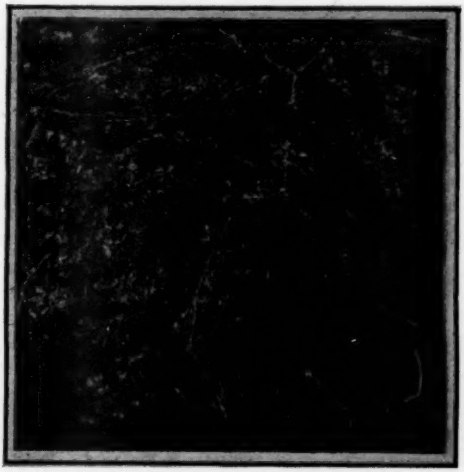

FIG. 6—SAMPLE 615. SHOWS MARTENSITE IN CRYSTAL GRAINS SURROUNDED BY CEMENTITE. ETCHED WITH NITRIC ACID. MAGNIFICATION 570 DIA.

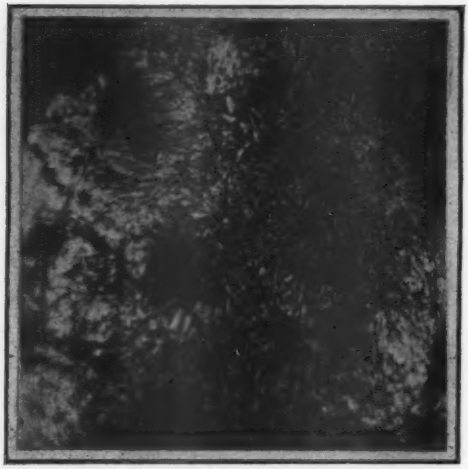

FIG. 7—SAME SAMPLE AS FIG. 6, EXCEPT THAT SODIUM PICRATE WAS USED IN ETCHING, TO DARKEN THE CEMENTITE. MAGNIFICATION 570 DIA.

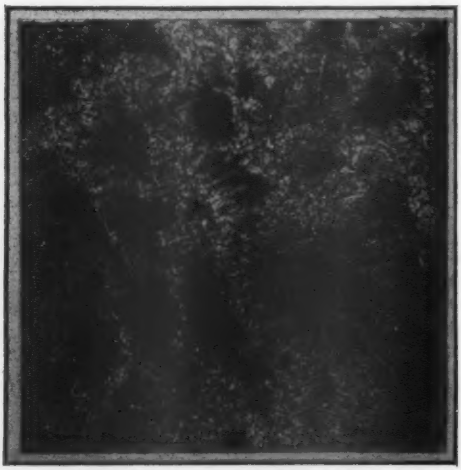

FIG. 8—SAMPLE 628. MALLEABLE BAR HEATED TO 1670 DEGREES FAHR., AND QUENCHED. SHOWS CLOSE GRAINED STRUCTURE, GREATLY RESEMBLING HARD STEEL. ETCHED WITH NITRIC ACID. MAGNIFICATION 100 DIA.

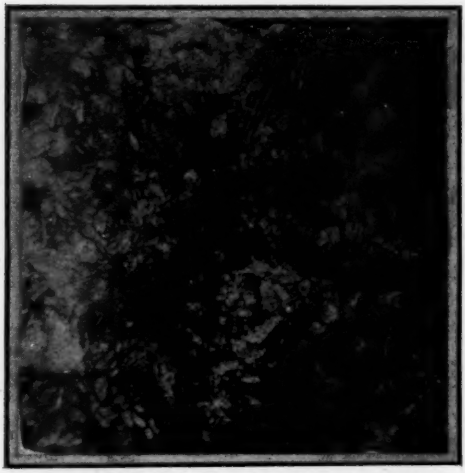

FIG 9.—SAME SAMPLE AS FIG 8 BUT HIGHER MAGNIFICATION. STRUCTURE APPEARS TO BE MAINLY SORBITIC-PEARLITE, WITH MARTENSITE. ETCHED WITH NITRIC ACID. MAGNIFICATION 250 DIA.

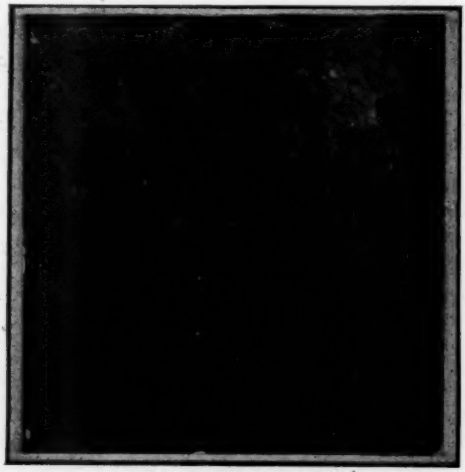

FIG. 10—SAMPLE 611. SHOWS VERY FINE GRAIN, STEEL-LIKE FRACTURE. ETCHED WITH ALCOHOLIC PICRIC ACID. MAGNIFICATION 100 DIA.

Sample 611

A malleable bar was heated to 1670 degrees Fahr., and quenched at that temperature, then reheated at 1200 degrees for one hour, and air cooled. The ultimate strength was 93600 pounds, elongation 2.5 per cent and hardness 34. Sample 611 of Fig. 10 shows a very fine grain, steel-like fracture. Sample 611 in Fig. 11 shows a very uniform sorbite with a few spots of cementite. Fig. 12 is the same specimen as of Fig. 10 and 11 but at a higher magnification.

Sample 623

A malleable bar, heated to 1670 degrees Fahr., and quenched, was then reheated to 1200 degrees Fahr., and held for three quarters hour, and air cooled. This gave an ultimate strength of 108165 pounds, elongation 2.5 per cent and hardness 25. Sample 623 is shown in Fig. 13 with a structure which is probably sorbitic pearlite with patches of cementite. Fig. 14 is the same as Fig. 13, but higher of magnification. White needles of cementite are seen with a background of sorbite. Fig. 15 is the same as Fig. 14 but the cementite is etched black with sodium picrate.

Sample 624

A malleable bar was heated to 1670 degrees Fahr., and quenched, then heated to 800 degrees Fahr., and air cooled giving an ultimate strength of 143260 pounds, elongation 1.5 per cent and hardness 30. A microphotograph of sample 624 is shown in Fig. 16 with a structure apparently sorbitic pearlite, while in Fig. 17 with a higher magnification it shows a background of sorbite, with needles of cementite. Fig. 18 shows the same sample but at a higher magnification.

Hard Iron

For purposes of comparison there is shown microphotographs of ordinary white iron before annealing. Fig. 19 shows hard iron, the white structure being cementite, the dark pearlite. Fig. 20 shows the same hard iron at a higher magnification. The ultimate strength was 36500 pounds, elongation 0 and hardness 50.

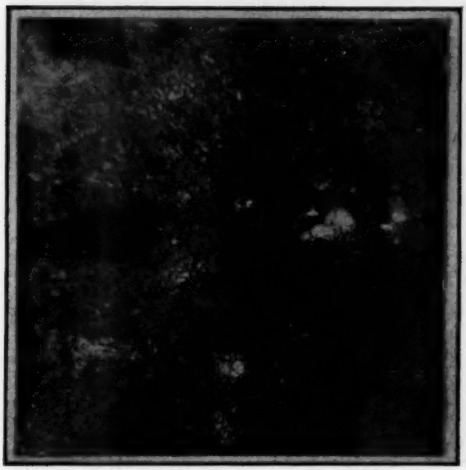

FIG. 11—SAMPLE 611. VERY UNIFORM SORBITE. SHOWS A FEW SPOTS OF CEMENTITE. ETCHED ALCOHOLIC PICRIC ACID. MAGNIFICATION 250 DIA.

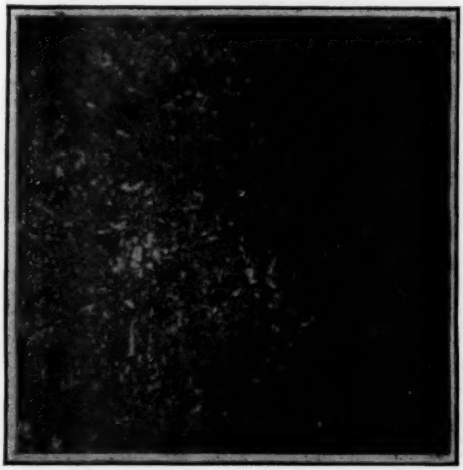

FIG. 12—SAME SAMPLE AS FIG. 11 BUT HIGHER MAGNIFICATION. ETCHED ALCOHOLIC PICRIC ACID. MAGNIFICATION 570 DIA.

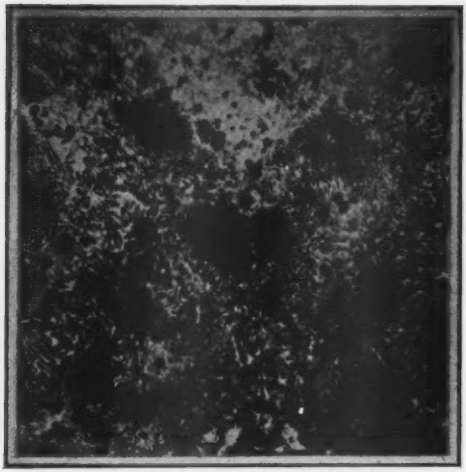

FIG. 13—SAMPLE 623. PROBABLY SORBITIC PEARLITE WITH PATCHES OF CEMENTITE. ETCHED NITRIC ACID. MAGNIFICATION 100 DIA.

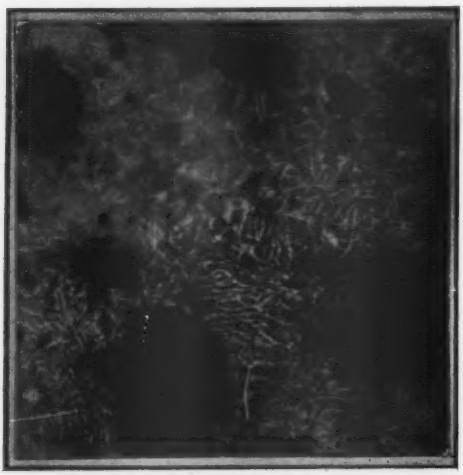

FIG. 14—SAME SPECIMEN AS FIG. 13, BUT HIGHER MAGNIFICATION SHOWING WHITE NEEDLES OF CEMENTITE, WITH BACKGROUND OF SORBITE. ETCHED WITH NITRIC ACID. MAGNIFICATION 250 DIA.

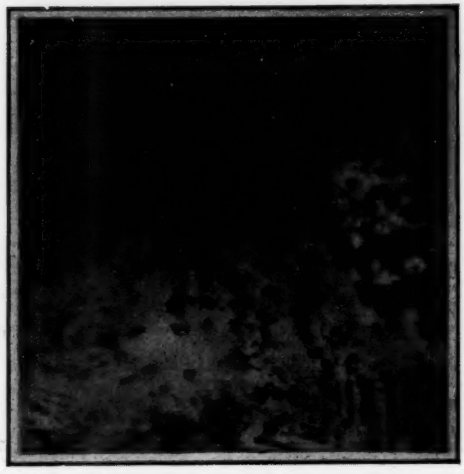

FIG. 15—SAMPLE 623, SAME AS OF FIG. 14 BUT CEMENTITE IS ETCHED BLACK WITH SODIUM PICRATE. MAGNIFICATION 570 DIA.

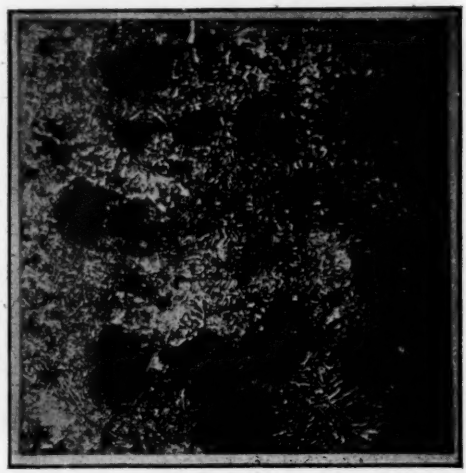

FIG. 16—SAMPLE 624 SHOWING STRUCTURE APPARENTLY SORBITIC PEARLITE ETCHED WITH NITRIC ACID. MAGNIFICATION 100 DIA.

FIG. 17—SAME SPECIMEN AS FIG. 16 BUT HIGHER MAGNIFICATION, SHOWING BACKGROUND OF SORBITE, WITH NEEDLES OF CEMENTITE. ETCHED WITH NITRIC ACID. MAGNIFICATION 250 DIA.

FIG. 18—SAME SPECIMEN AS FIGS. 16 AND 17 BUT AT HIGHER MAGNIFICATION. ETCHED WITH NITRIC ACID. MAGNIFICATION 570 DIA.

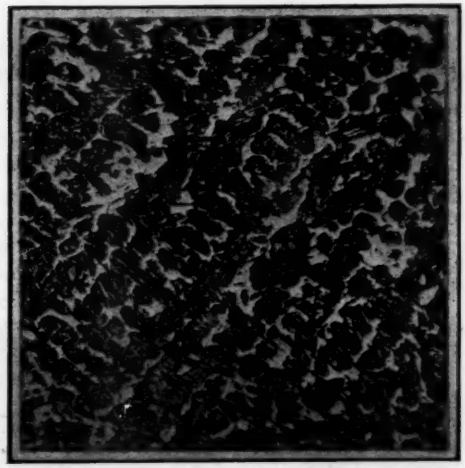

FIG. 19—ORDINARY WHITE IRON BEFORE ANNEAL, SHOWING WHITE PORTIONS AS CEMENTITE, DARK AS PEARLITE. ETCHED WITH ALCOHOLIC PICRIC ACID. MAGNIFICATION 100 DIA.

FIG. 20—SAME AS FIG. 19, BUT AT HIGHER MAGNIFICATION. ETCHED WITH ALCOHOLIC PICRIC ACID. MAGNIFICATION 570 DIA.

Normal Malleable Cast Iron

Fig. 21 shows normal malleable cast iron, annealed, with an ultimate strength of 54120 pounds, elongation 18.0 per cent, and hardness 16. Grains of ferrite and nodules of temper carbon appear in the microphotograph.

Hardened Malleable Shows Possibilities

While the subject of hardened malleable has not been investigated to a great extent, the experimental data shows a field for research, and probably for commercial processes. A

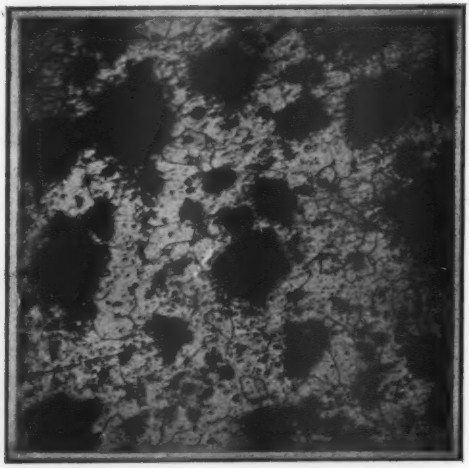

FIG. 21—NORMAL MALLEABLE CAST IRON SHOWING GRAINS OF FERRITE AND NODULES OF TEMPER CARBON. ETCHED ALCOHOLIC PICRIC ACID. MAGNIFICATION 100 DIA.

properly made malleable casting offers great possibilities, for as malleable, it is extremely soft, and almost free from combined carbon. By proper heat treatment, a desired part of the carbon may be recombined, giving a metal of the required hardness. A slightly more complex heat treatment will produce a moderately hard, very strong material, such as sample 68-1, which had 94844 pounds per square inch ultimate strength, 78664 pounds elastic limit, and 7.5 per cent elongation.

Just what would be the commercial field for malleable castings either wholly, or partly, hardened, is of course debatable, but it seems probable that such castings will be used in certain lines.

Several advantages of such material are apparent, and it may not be out of place to mention such advantages, coupled with illustrative examples.

1. Where part of castings must be sufficiently hard to undergo great shocks without "flowing", or fracture, while the bulk of the castings must be soft and tough. Example—Ordinary claw hammer. The face can be hardened by a single, rapid heat treatment, to a hardness of say 50 scleroscope, while the remainder of casting is extremely tough.

2. Where a good deal of machine work is required, this can be done first, then casting, or part of it, can be hardened. Example—Machine parts subject to wear. Machine operations can be made at high speed on the soft malleable, then the part subject to wear can be hardened, as required.

3. Where a smooth surface is needed, or where light sections must be run, the well known advantages of malleable along these lines can be utilized, while a brief heat treatment will change the metal to what is practically hardened steel. Examples —Certain articles of cutlery and hardware, where the handles must have considerable toughness, while cutting edges must be hard, and surface of whole casting is required to be smooth. For instance, wire cutters.

4. Where part of the casting must resist a file. Example—Automobile locks, part of which must be tough, part hard.

On account of its flexible composition, hardened malleable offers an infinitely wide field for varied physical properties, and when the desired qualities are known, a very little experimentation should tell whether a suitable material could be produced commercially.

One might almost substitute the words "hardened malleable" for the word "steel" in the recent statement of Professor Sauveur, when he said: "These three basic treatments may be called, softening, strengthening, and hardening. It is obvious

that the gradual transition of one constituent into another, as for instance of martensite into troostite, may result in the presence in the metal of these two constituents, in an infinite number of proportions, hence that the physical properties of steel may be made to vary by an infinite number of steps."

Table I

Sample	Ultimate Strength	Per cent Elongation	Elastic Limit	Scleroscope Hardness
Hard Iron	36500	0		50
Malleable	54120	18.0		16
No. 61—Quench 1980	33354	1.0		42
No. 615—Quench 1980-D 1200	69312	1.5		33
No. 628—Quench 1670	33170	1.5		60
No. 611—Quench 1670-D 1200 1-hr	93600	2.5		34
No. 623—Quench 1670-D 1200 ¾-hr	108165	2.5		25
No. 624—Quench 1670-D 800	143260	1.5		30
No. 615-2—Quench 1630 Heat to 1400 Cool slow	90591	6.5	68723	25
No. 68-1—Quench 1630 Heat 1400 Cool to 800 Quench 800	94844	7.5	78664	30

The Adaptation of the Continuous Muffle Annealing Furnace to the Malleable Iron Industry

By Philip Dressler, Cleveland, O.

It is now somewhat more than four years since the subject of the Dressler Furnace was first brought to the notice of the American Foundrymen's Association at the Milwaukee meeting in the form of a discussion on Mr. Diller's interesting paper "Experiments in Annealing Malleable Iron." In this paper Mr. Diller described his experiments which indicated that ordinary black-heart malleable castings could be annealed satisfactorily in much less time than that normally consumed and that probably this time saving, together with a fuel and labor saving could be brought about in a practical fashion by the use of furnaces of the tunnel and car type.

Since that time a number of these furnaces have been and are being installed for annealing malleable castings. The first was installed by the Saginaw Malleable Iron Company in the winter of 1919 to 1920 and has been in operation since April, 1920, that is to say practically three years. In addition to this, the furnace at the National Malleable Castings Co., Cleveland, O. has operated about one and one-half years and that at International Harvester about the same length of time. It is possible now to present the results of several years of actual experience on the factory scale and to compare the anticipations of four years ago with the realizations of today.

The characteristic feature of the tunnel furnace is that any desired heat curve within reason can be established and maintained from the entrance end to the exit and that there is a uniform temperature throughout the cross section of the furnace. The castings are loaded on wheeled cars which are pushed by means of a hydraulic propeller in a solid train through the tunnel —a car being removed at the exit end every time one is

introduced at the entrance end. In this way all the cars receive precisely the same heat treatment and the operator's task is confined to maintaining a static temperature condition in the furnace which is manifestly simpler than trying to produce the same heat treatment in a number of intermittent furnaces, each of which usually has its own peculiarities of operation.

Therefore in designing a continuous tunnel furnace for annealing malleables the first thing required is a time temperature curve which will give good results.

Heat Curve Control

Fig. 1 shows such a curve. In this it will be noted that the temperature is raised as rapidly as possible to about 1600 degrees Fahr., maintained at that point for a period and then

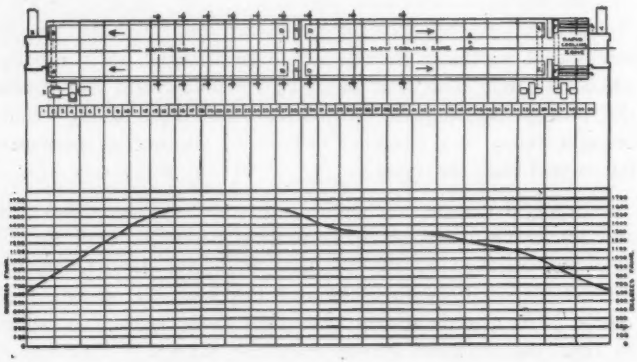

FIG. 1—TIME TEMPERATURE CURVE FOR CONTINUOUS MUFFLE ANNEALING FURNACE

allowed to drop fairly rapidly to 1350 degrees, then with greater slowness to 1300 and then finally as rapidly as possible to the emerging temperature. The exact periods required for the soak at 1600 and the slow cooling at 1300 have been found to vary widely for castings of different compositions and methods of preparation. Since the slow cooling especially at the critical point is so important to secure complete elimination of pearlite it was found necessary to introduce a means of heating the cooling zone in the critical range to offset the radiation losses and prevent the temperature from dropping too rapidly.

Plan of Furnace

Fig. 1 in addition to the heat curve, shows on the same scale of length a diagrammatic plan of the furnace as used for malleable annealing. X is the entrance; Y the exit. From A to B we have the regular Dressler combustion chambers into which the fuel is introduced at a number of burners on either side of the furnace, depending on the length of soaking zone desired. In this region the castings are raised to the full temperature and maintained at that point for the requisite length of time. The gases of combustion are drawn off at point A and pass through a regenerator box, Z, in which air is preheated to about 600 to 800 degrees Fahr. for use in burning the fuel. Leaving Z the gases of combustion pass out to a fan or stack.

At C there is a division in the kiln which hugs closely the ware on the cars and is designed to prevent heat interchange between the heating and cooling zones. From D to E we have a set of combustion chambers identical with those in the heating zone, except that they are of a smaller cross section. These are provided with a series of burners which can be thrown into operation at various points in the cooling to prevent over-rapid loss of heat. The products of combustion are exhausted by a fan at E. Provision is also made whereby cool air can be drawn through these chambers so that they can be used for cooling the ware as well as heating it, thus giving the widest possible range of control. At this point it might be interesting to state that the actual heat developed by the recalescence of the metal when it reaches the critical range is in most cases sufficient to cause a marked arrest in the rate of cooling through this range and in some cases, especially where the tonnage of iron on each car is great, this produces a sufficient slowing up of the cooling to produce good castings without the use of any of the auxiliary cooling zone burners, although even in these cases the burners are used to establish the curve when the furnace is heated up.

By the time the cars reach E the castings have cooled down below the critical range and can stand rapid cooling. Accordingly from F to G there is a series of steel pipes through which a large volume of cold air is drawn. The ware after passing through this region is ready for withdrawal.

FIG. 2—INSIDE OF FURNACE, LOOKING FROM THE ENTRANCE END IN TOWARD THE CENTER

The whole process of heating and cooling is thus under complete control and furthermore neither the products of combustion nor the cooling air are brought in contact with the castings, that is to say the furnace is completely muffled.

Construction Details

Having described the general features of the furnace the following series of pictures will show some details of its construction.

Fig. 2 shows the inside of the furnace, looking from the entrance end in towards the center. On either side will be noted the combustion chambers resting on benches which correspond in height with the platforms on which the castings are set. The cars travel on standard 80 pound rails and the lower portions which contain the running gear are cooled by means of cold air drawn through the sets of three steel pipes shown on either side at the bottom of the bench.

Fig. 3 shows a single section of combustion chamber, composed of four individual pieces. These sections are set one against the other to form the continuous chamber as shown in Fig. 1. The gases are burnt in the central space. The flues on the back and front are heated and acting as chimneys draw the furnace atmosphere in at the bottom and discharge it at the top as indicated by the arrows, thus maintaining a continuous circulation of the atmosphere around the castings and facilitating a rapid and even distribution of heat throughout the cross section of the furnace. The double walled construction of the combustion chambers serves the double purpose of facilitating this circulation, and permitting high flame temperatures to be maintained in the combustion chambers without overheating the castings, with a consequent gain in heat efficiency.

Fig. 4 shows the regenerator box in which the air is preheated by means of the exhaust gases. The air is blown through the coils in the brick lined steel box by means of the turbo-compressor on the left, at a pressure of about 1½ pounds. The air is heated up to about 800 degrees and the gases are reduced in temperature from 1400 to 800 degrees. These temperatures vary accordingly to the load on the furnace and the fuel burnt.

The hot air is carried off through the insulated steel pipe over the furnace and is distributed to the various burners. The products of combustion pass out of the top of the box down to a steel pipe under the floor and so to the exhaust fan.

The temperatures of the various zones of the furnace are controlled by a number of thermo-couples inserted through the arch. The drafts on the combustion chambers, pressure of air and

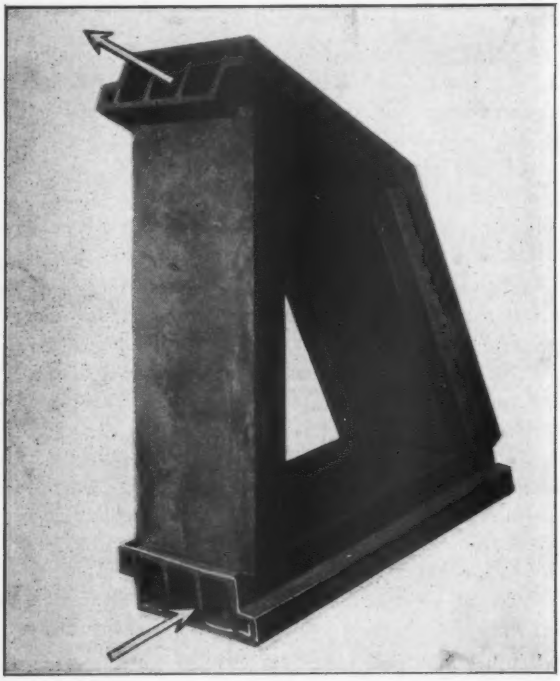

FIG. 3—SINGLE SECTION OF COMBUSTION CHAMBER

fuel, pressure exerted by the hydraulic propeller and other important data are recorded in the instrument room are and under constant supervision of burner operators. With these indications the operator is able to maintain the precise conditions at all times which give the best results.

Method of Operation

The above description indicates the general physical construction and equipment of the furnace. The next point of interest is the method of operation. One of the greatest advantages of the tunnel furnace is that the loading and unloading are concentrated at one spot enabling labor saving devices to be used profitably. A system of conveyors first worked out at Saginaw and later amplified by the International Harvester Company has proved to be a great labor saver in the dumping and packing of the pots.

Except in a few cases of very difficult castings which are liable to distortion, the packing has been eliminated. To protect the bottom castings from the load of those above, it was found necessary either to use pots with bottoms or to introduce separator plates between the pot rings. At Saginaw they are using separator plates which have to be handled independently of the pots. At the International Harvester Company this has been improved by casting bottoms integral with the pots. It was feared at first that this would offer difficulties and that there would be considerable loss of pots from cracking. These anticipations have not been realized and the design has been found entirely practical and a labor saver. The pots are provided with trunnions on diagonally opposite corners placed at such an elevation on the side of the pot that the latter is easily tipped upside down and the castings dumped out.

Fig. 5 shows a car on the transfer being removed from exit end of the furnace by means of a gasoline tractor. In the background to the right is shown the car puller, a device for separating the last car from the train and drawing it onto the transfer thus enabling the inner door to be lowered between it and the next car before the outer door is opened.

Fig. 6 shows a pot being lifted from the furnace car and the castings dumped out into a truck.

Fig. 7 shows the pots being refilled while passing down the roller conveyor. The castings to be annealed are brought to the side of the conveyor conveniently for the men to place them in the pots. The pots are filled, as far as possible, with an

FIG. 4—REGENERATOR BOX IN WHICH THE AIR IS PREHEATED BY MEANS OF THE EXHAUST GASES

assortment of large and small castings so as to get the tightest possible loading.

When the pots reach the end of the conveyor they are loaded by means of a small hand operated crane back onto the tunnel kiln cars. The method of operation is shown in greater detail in Fig. 8. The usual procedure is to accumulate a sufficient supply of loaded cars to carry over the week end without packing. On Saturday there is a maximum of loaded cars on the return track at the head end and a minimum of cars not yet unloaded at the tail end. On Monday morning the position is reversed and there is a large supply of cars ready to be unloaded, while the supply ready to go into the furnace has been exhausted.

Fig. 9 shows the entrance of the furnace. In order to make the picture more interesting the outer door has been opened before the car was pushed completely beyond the inner door, so that the furnace is completely open to the atmosphere. This is not the usual procedure. Under regular operating conditions the exterior door at either end is not opened until the interior door has been lowered. On the left of the picture is the hydraulic propeller with the pusher rod passing through the end wall of the kiln. The propeller pushes forward the whole train in the kiln one car length at each stroke, thus permitting another car to be placed at the entrance end and one to be withdrawn at the exit.

It will thus be seen that the general conditions of operation of this furnace permit of a very satisfactory organization of the packing and dumping of pots, all of which is carried on under the most desirable conditions with the elimination of the dirt and disorder usually typical of annealing rooms where intermittent furnaces are in use.

Life of Refractories

One of the points of greatest importance in connection with a furnace of this description concerning which many questions are asked is the life time of the refractories. It is evident that unless such a furnace can run continuously for a long period without interruptions for repairs it can not be a commercial success regardless of how well the castings are annealed.

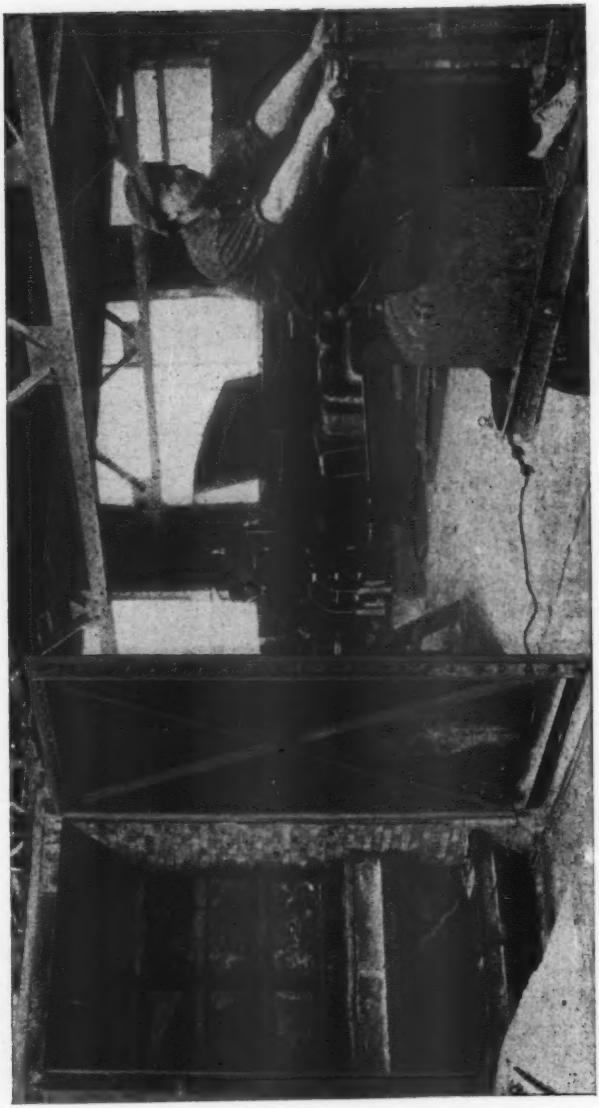

FIG. 5—A CAR ON THE TRANSFER BEING REMOVED FROM THE EXIT END OF THE FURNACE BY MEANS OF A GASOLINE TRACTOR

The main tunnel arch is not subject to any flame action, is not heated above 1750 degrees Fahr., is maintained at a steady temperature and is, therefore, not subjected to any destructive agencies. If well constructed in the first place it is practically everlasting and will probably endure for a generation without repairs. The only portions which are liable to suffer in use are the combustion chambers and the whole problem is confined to these. It has been found that the life of these refractories is to a great extent influenced by the fuels used. Some fuels are more destructive in themselves than others and from their nature more dangerous to use.

When they installed their Dressler furnace the Saginaw Malleable Iron Company desired it to be oil fired since they already had installed oil burners on their air furnaces and wished their whole plant to operate on this fuel. This was the first experience of the Dressler Company with fuel oil, as previously all the installation had been gas fired, and there were a number of lessons to be learned. Before the difficulties encountered were finally mastered, unfortunately a good deal of damage was done to the combustion chambers which after a period of about six months operation necessitated a shut down and the replacement of some of the refractories.

Troubles Encountered Using Oil

The difficulties encountered can be summed up under two heads:

(1) Difficulties in obtaining a regular and reliable supply of oil to the burners.

(2) Deleterious action of the oil flame on the refractories.

The design as first installed at Saginaw was not satisfactory in that the Dressler furnace was supplied from the same pumping unit which also supplied the air furnaces. These took a very much larger amount of oil than the tunnel so that when they were turned on and off large fluctuations in the pressure of the oil supply to the tunnel burners were experienced causing at some times large excesses of fuel and at other times the burners to go out. These fluctuations could not be anticipated by the operators and as a result of the alternate overheating and chilling the combustion chambers were damaged.

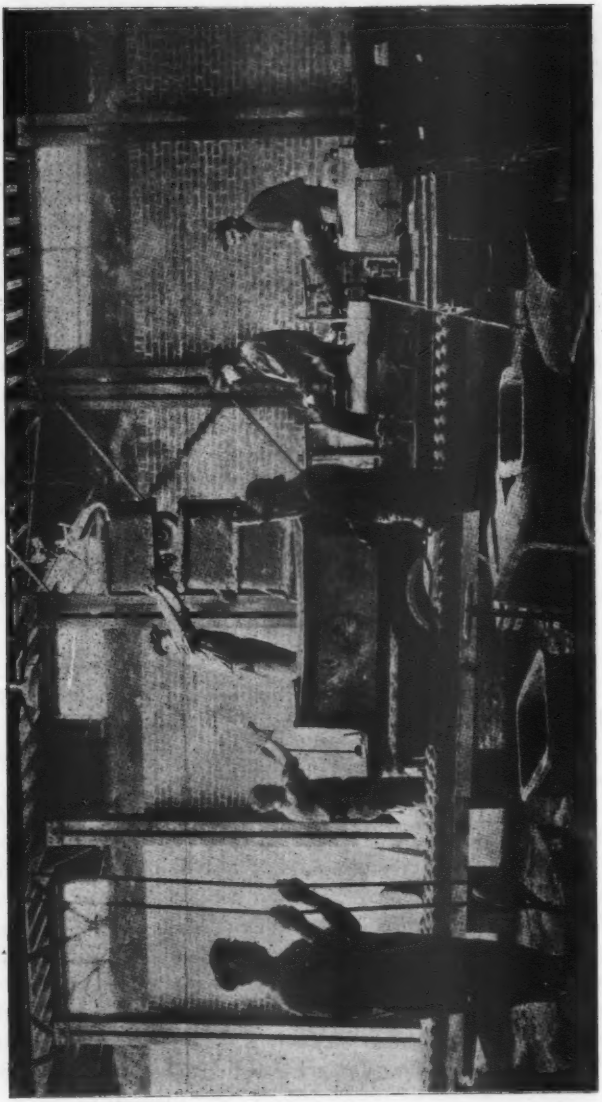

FIG. 6—A POT BEING LIFTED FROM THE FURNACE CAR AND THE CASTINGS DUMPED OUT ONTO A TRUCK

The other big difficulty was due to the insufficient straining of the oil before delivery to the burners. The individual burners on the tunnel were probably not taking an average of more than five or six gallons of oil per hour each so that the valve openings were very small and easily clogged. Until very thorough straining facilities were provided the burners were continually going out due to this cause and again there was a chilling of the refractories and damage.

Action of Oil Flame on Refractories

When these two difficulties had been adjusted there was no further trouble from irregular oil supply and this source of damage was eliminated. The other difficulty, viz., the action of the oil flame on the refractories was more fundamental. It was very soon discovered that the flames were having a fluxing action on the combustion chambers. These first became glazed and then began to run. The material of the sides and tops was actually removed by a process of "washing down" and an inch or more of glass collected on the bottom of the chambers. Investigation showed that this glass contained over 7 per cent of soda and potash and in view of the fact that the refractories originally contained less than 1 per cent it was apparent that the oil was a source of alkalis. Analysis showed that there was a mineral residue in the oil amounting to about 0.1 per cent. This does not appear very much but when it is remembered that 5 pounds of soda is sufficient to flux 100 pounds of refractories and the daily fuel consumption is in the neighborhood of five tons, it will be seen that the 10 pounds of salt in this fuel is capable of fluxing no less than 200 pounds of refractories and that the possibilities of trouble from this source in the course of months of operation are very great. The discovery of the presence of salt in the oil came as a great surprise to everybody—apparently even the oil companies were ignorant that there was this source of difficulty present. Experiments showed it to be almost invariably present to a greater or less extent in the oils from the mid-continent field, although some of the heavy Mexican oils used on the Eastern Seaboard were apparently free from it. It must be remembered that fuel oil is the residue left after the valuable volatile elements, gasoline,

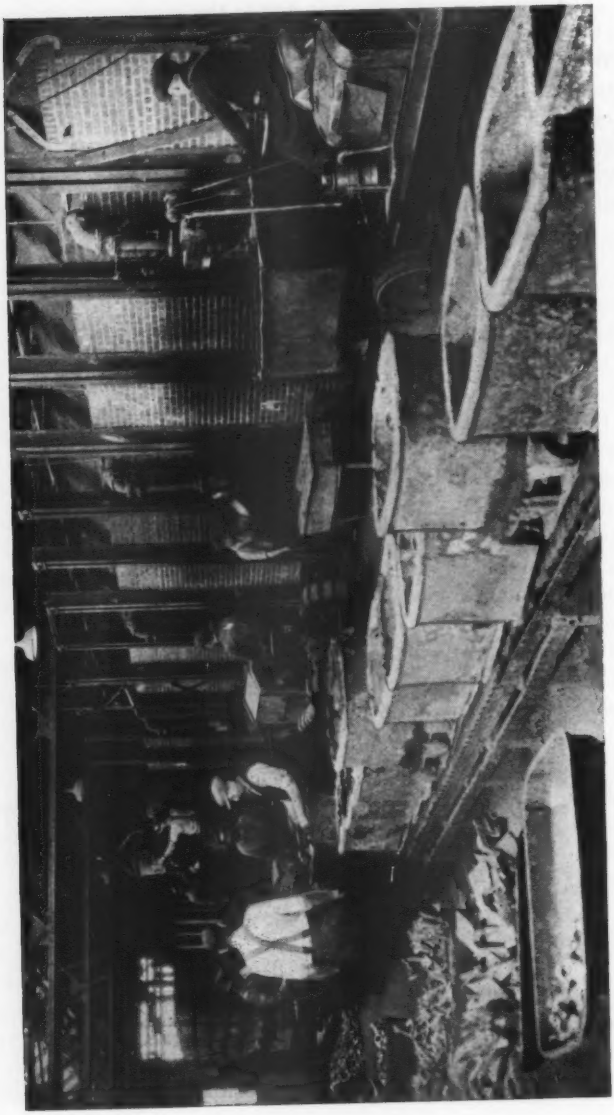

FIG 7—POTS BEING REFILLED WHILE P ASSING DOOWN THE ROLLER CONVEYOR

kerosene, etc., have been distilled off and, therefore, contains all the impurities of the original crude oil in a concentrated form.

Overcoming Troubles From Fluxing Materials in Oil

There were two ways in which the difficulty could be overcome, either by the use of oil which was free from alkalis or by developing refractories which were resistent to them. It was found that the only oil which was available that was positively free from alkalis was a distillate, known as "Gas Oil" 32 to 36 degrees beaume. This is used by gas works for enriching water gas. It is an admirable fuel and very easy to handle but is about 1 cent per gallon more expensive than ordinary fuel oil.

After considerable effort in attacking the problem from the other angle and producing refractories which were resistent to the oil action, successful results were obtained. Some of these have now been in use in the National Malleable Company's furnace for about eighteen months under midcontinent fuel oil conditions and show no attack.

In addition there is another point with regard to fuel oil which makes it difficult fuel to use. It is tremendously concentrated. One cubic foot of oil develops on combustion as many B. t. u. as one thousand cubic feet of natural gas or 7000 cubic feet of producer gas. For this reason its regulation is a very much more sensitive operation. A slight increase in a valve opening or in the pressure will largely increase the fuel at a given burner and develop a tremendous excess heat which may punish the refractories. Furthermore in itself the oil flame is naturally very hot. The oil has to be atomized or vaporized and this is bound to give rise to a rapid combustion and an intense local heat. It is largely for this reason that, where possible, the use of gas rather than oil (preferably cold, clean producer gas) is advocated. This is a very easily controlled fuel, giving a gentle and not intense flame which is extremely easy on the refractories. At Saginaw it found the refractories were frequently heated to 2500 or 2600 degrees—in the case of the producer gas fired furnaces the maximum temperature appears to be around 2200 degrees, even though in the two cases the

FIG. 8—POTS WHICH HAVE REACHED END OF ROLLER CONVEYOR, BEING LOADED ONTO THE TUNNEL KILN CARS BY MEANS OF A SMALL HAND OPERATED CRANE

temperature of the furnace proper is the same, viz., about 1650 degrees. The producer gas flame is, however, longer and the heat is given off over a larger area of the combustion chambers.

With the best refractories using this type of fuel we have had no trouble at all and the first installation at the International Harvester has operated now for eighteen months with no damage whatever. We see no apparent reason why it should not continue to operate for several years without repairs.

Advantage of Gas as a Fuel

There is one other advantage in gas over oil as a fuel. It is possible to regulate the proportion of air to fuel with much more accuracy in the former case and once regulated it will continue steady and free from fluctuations. At the International Harvester Company it has been found possible to maintain the CO_2 in the exhaust gases at from 19-20 per cent constantly, with practically no free oxygen at any time. The atmosphere surrounding the castings on the cars always approximate that of the combustion gases. The advantage of a high CO_2 and low oxygen content in these gases in minimizing oxidation, both of the pots and castings, is evident.

It is not the intention of this discussion, however, to give the impression that oil cannot be satisfactorily used in this furnace. With a well designed oil system and suitable refractories to withstand the deleterious action of the oil flame it can be and is being used with very excellent results. The Saginaw Malleable Iron Company have operated with this fuel for three years and have had what they consider very good satisfaction with it. They report that the furnace has been under fire since January, 1922 and that no repairs are expected till the beginning of 1924 at the earliest. Indeed in some parts of the country, such as New England where coal is expensive and the heavy Mexican oils relatively cheap it is the only logical fuel to use. The same would be true in the western states and on the coast.

Increase Output of Annealing

Having now described the construction and operation of the furnace it will be interesting to see to what extent the antici-

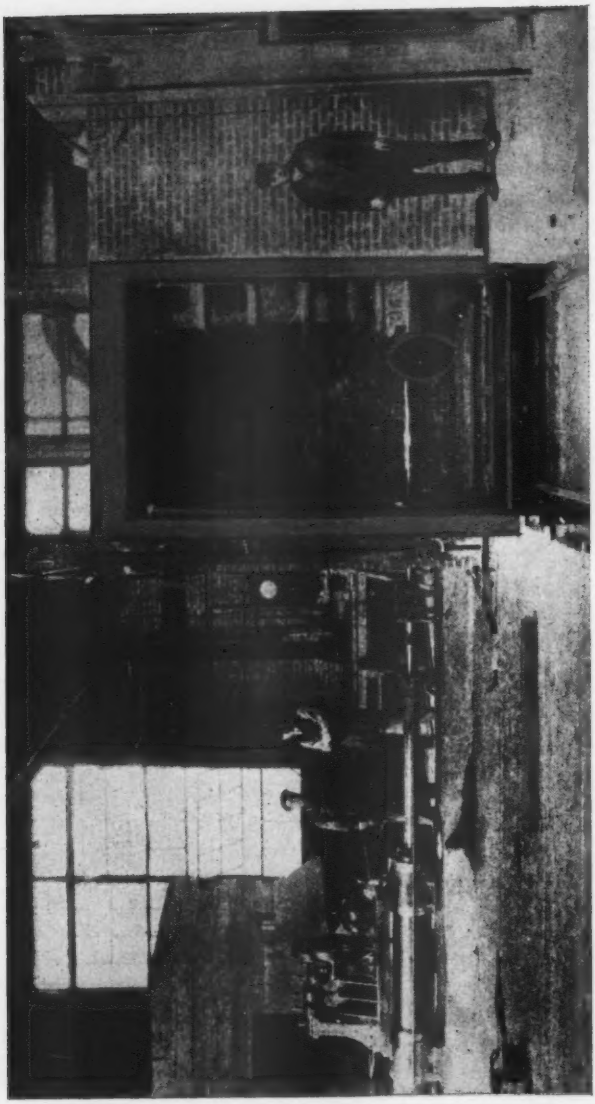

FIG. 9—ENTRANCE END OF FURNACE, ON THE LEFT IS THE HYDRAULIC PROPELLER WITH THE PUSHER ROD PASSING THROUGH THE END WALL OF THE FURNACE

pations of savings and improved quality have been realized in practice.

Firstly—With regard to the time required for annealing, this has been found to differ widely for castings prepared under different conditions and of different mixtures. At Saginaw it has been found possible to speed up the furnace to a capacity of 13 to 14 cars per day, giving respectively a cycle of 111 or 103 hours. It has been possible to put rush orders through the foundry and annealing room and ship them within a week, thus fulfilling Mr. Diller's prognostication that this could be done. The International Harvester furnace has been operating successfully on a basis of 13 cars per 24 hours, giving a cycle of 111 hours. Other types of material, however, have taken more time. It has not been commercially advantageous at the National Malleable plant to use less than a 200 hour cycle although it is hoped by modification of the heat curve that the time may be reduced.

The tonnage capacity of the furnaces has been found to depend upon a variety of circumstances, such as the shape of the castings, whether they can be packed tightly or not, whether it is necessary to use any packing material and the heat cycle. The highest tonnage has been obtained at Saginaw. This furnace was originally designed to anneal 45 tons per 24 hours but has operated continuously at a capacity of a little over 57 tons per day or 400 tons per week. At this point it may be of interest to note, it is entirely possible to operate a furnace at far below its rated capacity and still get good results. For months the Saginaw furnace was operated on four to six cars per 24 hours. Under these conditions it is necessary to make some adjustments in the cooling curve in order to prevent the ware from losing its heat too rapidly. On a slow schedule, of course, the overhead, labor and fuel charges per ton mount rapidly but the operation of the tunnel was justified by the better quality, low pot loss and ability to get out rush orders when necessary.

Fuel Consumption

The fuel consumption per ton is determined by a number

of factors, other things being the same, it is least when the furnace is operated at one hundred per cent of rated capacity. As the tonnage is dropped below this point it goes up slowly at first and then rather rapidly for the reason that the radiation and exhaust losses become more and more important in relation to the heat absorbed by the castings. If the furnace is forced above its capacity the fuel consumption per ton also rises but quite slowly. Another point which also influences the fuel consumption per ton is the relation of the weight of the castings to that of the pots and other nonproductive material heated. This is determined largely by the type of castings passing through the foundry. When the Saginaw Malleable Iron Company furnace was started up on the 45 ton capacity 26 gallons of fuel was used per ton. At the present time with a run of castings which cannot be as tightly packed in the pots, on a capacity range of 44 to 57 tons the consumption varies from 28 to 35 gallons of fuel oil per ton annealed.

At the International Harvester Company the lowest fuel consumption to date has been about 415 pounds of coke per ton, at a time when they were running fairly heavy castings on a 45-ton capacity basis. Even at that time they were not loading the pots as heavily as at Saginaw. If they had done so the fuel consumption would have figured slightly under 400 pounds. Under normal operation conditions where a large proportion of the tonnage consists of light binder parts, the consumption is about 450 to 500 pounds on a full production basis.

Life of Pots

The life of the pots has proved very satisfactory in this furnace, being at least from three to four times as great as in intermittent furnaces. It has been found to be somewhat dependent upon the fuel. It is far easier to keep the furnace atmosphere in a non-oxidizing condition with producer gas than with oil. But the principal cause of the long pot life is probably that at no time and in no portion of the furnace is a higher temperature experienced than is actually required for the annealing process. In the intermittent ovens on the other

hand there is normally a big difference between the temperatures around the fire boxes and those near the floor of the furnace near the door. In order to raise the latter to a minimum of 1600 degrees Fahr. a temperature of 1800 degrees Fahr. will often have to be carried at the fire boxes. This variation is entirely eliminated in the Dressler furnace. The shorter cycle will also have a beneficial effect on the pot life. In the year 1922 the Saginaw Malleable Iron Company used 2053 pots to replace those discarded. In this period they annealed 17,600 tons of castings or an average of 8.6 tons per pot thrown out. The average load on a car was 4.4 tons, packed in 24 pots; the load per pot, therefore, was 356 pounds. On this basis the average number of trips per pot discarded was 47. The Saginaw Malleable Iron Company figure the life at from 45 to 55 trips per pot which compares with the life of 8 or 9 heats in intermittent furnaces. At the International Harvester Company operating under producer gas conditions the life appears still better. So far it is impossible to give final figures because the furnace has only been operating 18 months and very few of the pots have so far been thrown out. The operators expect that the average will figure out somewhere between fifty and one hundred trips and will approximate the higher figure.

Labor Costs

With regard to labor these furnaces have shown a saving of about 40 per cent. At the present time at Saginaw, on the basis of packing and dumping in six days the tonnage produced through the furnace in seven days, that is to say about 70 tons per day, the labor is as follows:

To operate the furnace—	
One man on each eight hour shift.....	3 men
To pack the castings, load and mud the pots and unload and dump the castings.....	13 men
Truck driver to haul the castings away.....	1 man
Tractor driver to put cars in and out of kiln and spot cars on return track.....	1 man
Total	18 men.

If the Saginaw Malleable were using the newer type of pots with bottoms and dumping trunnions instead of separator plates, they would be able to dispense with one man at least for the loading. Furnaces operating on producer gas require additional labor for the full 24 hours to operate the producers. This to some extent offsets the low price of solid fuel in comparison with oil.

Obtain Quality in Castings

The final and probably most important point is that of quality, for manifestly no saving in other directions would be of any interest if quality could not be maintained. This is a very difficult matter to reduce to comparative figures. In the first place it is naturally impossible to produce well annealed malleables in any furnace unless the composition of the metal is just right all the time. Furthermore, the comparative results will depend largely upon the degree of care used in the control and operation of the intermittent furnaces. A constant supervision is essential when operating the continuous furnace and for this reason there is a tendency for a newly installed tunnel furnace to be run much better than intermittent furnaces were run previously, with consequent improvement in results. Discounting these considerations, however, there is no doubt that this type of furnace offers a very much easier and more accurate control than the regular intermittent malleable annealing ovens.

Discussion—Continuous Annealing Furnace

E. D. Halsey.—I would like to ask if, in the localities where it is not economical to use either fuel oil or gas, this furnace is adapted to coal?

P. Dressler.—In this type of furnace where combustion chambers are used, it is not possible to use any kind of fuel which has an ash, for the reason that the chambers would soon

be filled up with slag or dust, which would have the effect of preventing their use after a short while. The fuels used so far have always been either liquid or gaseous.

V. D. Miller.—I would like to ask if there has been any thought given to a recuperative type of furnace, whereby you would have a double-track furnace and send the cars through in opposite directions, the advantage of that being that the outgoing hot car would give up some of its heat to the incoming cold car, preheat it, and thereby a considerable amount of fuel could be saved in that way, it seems to me.

P. Dressler.—I have given a good deal of thought to it in the past. The objection we have always had to building a furnace of that type is that you cannot independently control the heating and cooling sides of the circle. If you remember that curve which I indicated as giving such satisfactory results, there was a very rapid rise in temperature to the highest point, and then a hold, and then a cooling section which was equal in length to the whole of the heating section. Now if you wish to run opposite trains, you would have to have for both of them at least the same length of high heat zone that you have at the present time, and in addition you would have to have the slow cooling at each end, so that on an equivalent amount of capacity, you would have to have a very much longer furnace.

V. D. Miller.—What is the relative weight of the pot to the charge it contains?

P. Dressler.—At Belle City the weight of the pot is 490 pounds and the weight of the charge is 460 pounds; at the Harvester plant, the pot weighs 550 pounds and the charge 400 pounds.

Mr. Fitch.—As far as preheating is concerned, there is a type of furnace which uses some of the heat by convection and radiation, boxes passing out of the furnace will give you as high as 500 degrees Fahr., and that is carried on into the hot zone of the furnace where the heating is extended as high as 950 degrees Fahr., and it saves about 18 per cent of the fuel that is used, when the same fuel is burned with atmospherical temperature at combustion, and that furnace can be operated at any variation or within 5 degrees all the way

through the zone, using Mr. Schwartz's idea of the furnace chamber being maintained at, say 1600 degrees Fahr., and the second chamber 1300, and the third chamber cooling as rapidly as you can cool it.

V. D. Miller.—Would it be possible to save any weight if, instead of using pots, you used trays, stacking one above the other so that the weight of the piece would not support the tray, but have a separate support? What I am trying to get at is that we do not want to heat up any more useless material than possible, and if you had a broad tray, something like the top of that table, say 6 or 8 inches apart in height, building up a car that way, and put your pieces in, could you not save considerable weight rather than by using pots?

P. Dressler.—It is true you would eliminate a certain amount of pot sag, but you would have more pot bottom, as it were. The pot is nothing but a tray with sags; in any case you have to have a certain number of vertical supports; if, instead of having a pot which is 20 inches high, you have trays at intervals of 8 inches, you are thereby increasing the number of horizontals anyway, and personally I have grave doubts whether you would save anything at all. If you could make the trays sufficiently high so that you could pile the stuff upon the car several feet high, it would be all right, but then you would be up against the problem of getting the castings out.

Malleable Iron Cast in Small Quantities

By S. J. Felton, Cincinnati

This paper deals primarily with the melting of malleable cast iron in furnaces not ordinarily used for this metal, and the points discussed are mainly those in which the practice differs from that usually employed. The facts herein presented should be interesting to foundrymen contemplating the production of malleable in small quantities in conjunction with gray-iron, steel, or brass foundries. Malleable iron can be melted in brass foundry crucible furnaces, but the small quantities produced, coupled with the difficulty in most cases, of obtaining sufficiently high temperatures, make this method impracticable with the usual installation. The use of the electric furnace in this field is considered later. High grade, free-annealing malleable iron can be melted in oil furnaces, such as are used in brass foundries, and the following discussion is based on the use of 500 and 1000-pound, horizontal, barrel-type, non-crucible, tilting furnaces, using oil as a fuel.

Raw Materials

The pig irons ordinarily used for malleable are perfectly satisfactory, but they should be of small size, and care must be used each heat in getting representative pieces for the charge because of the small quantities used. Plain carbon steel, malleable scrap, ferrosilicon, and ferromanganese make up the other ingredients of the charge. Naturally, materials containing chromium should be avoided. Although carbon is not absorbed by the charge, crushed coke or other form of carbon may be added to crushed coke or other form of carbon may be added to re-retard oxidation of this element. Bought malleable scrap should never be used, as the analysis fluctuates greatly, and high sulphur is liable to be encountered. Slag, burned out mill-scale, or sand, make satisfactory packing materials for annealing. If

the packing material becomes oxidizing in nature, it may be neutralized by coke additions. The melting furnace may be lined with either fire-clay or silica.

Melting Practice

The time of melting will ordinarily be under two hours, and the melting losses will average about .40 C., .30 Si., and .20 Mn. As the change is very rapid when the metal is hot, particular efforts must be made to cast and break fracture samples quickly, so as to catch the metal at the right point. Therefore, smaller samples and quicker cooling than is used in air-furnace practice, must be had. A sample, cast in the impression made by the end of a shovel handle and water quenched after air cooling to below a red heat, is satisfactory. Ordinarily the metal is tapped on an almost white fracture showing a slight graphite precipitate. Although according to air-furnace practice this fracture in such a small, quickly cooled, sample, would indicate high carbon and silicon, the metal changes so rapidly in the oil furnace that this fracture will give a heat analysis of about .90 Si., 2.50 C., and .20 Mn., if the mixture was made up taking into consideration the losses given above. The heat must be tapped quickly, and as the losses continue while the metal is being poured from the furnace, the last part of the heat should be doped with ferro-silicon unless heavy work is being poured.

Until one becomes thoroughly acquainted with the process, each heat should be analyzed as quickly as possible so as to get a line on just what the furnace is doing. Castings should also be broken to be sure that no graphite is present. The losses are liable to vary in different furnaces, and with different materials charged. If the metal comes down too slowly, steel may be added to aid oxidation; if too quickly ferrosilicon may be used. If considerable time is spent doping a heat, cognizance must be taken of the manganese loss and ferromanganese should be added. If very thin work is to be poured, it is sometimes advisable to tap on a darker fracture than the one mentioned above, while for heavy work a white fracture on a larger sample should be obtained.

For light work, the metal must be handled quickly in thick

lined ladles of not over 100-pound capacity. Unless the heats are running very uniformly in analysis, the scrap for each heat should be kept separate, as fairly close figures on the mixture to be charged must be obtained in melting such small quantities of metal. If larger amounts of metal are needed, several furnaces may be run at the same time. This puts quite an analytical burden on the laboratory, but when heats are running smoothly, and the same materials are being charged, it is possible to obtain uniform results if a single Si. or C. is run on each heat, provided a complete analysis is obtained on one heat from each furnace every day. Before this method is adopted, however, one should be expert at drawing deductions from the fracture samples, and the furnaces must be well understood. The P. and S. should run under .20 and .05 respectively, and they remain practically constant during the heat. It must be admitted that the methods of sampling and analysis stated here probably seem somewhat haphazard to a strictly up-to-date malleable man, but the exigencies of the process necessitate just such procedure, and the uniformity of metal obtained under these conditions is surprising.

Annealing

Oil-furnace malleable is a free annealing iron, thus soaking at 1600 degrees Fahr., for 48 hours and cooling at 10 degrees per hour gives complete annealing. In many instances quicker annealing than this is satisfactory. Off-analysis metal anneals more readily than air-furnace iron of the same analysis, but naturally in most cases, unless the analysis is correct, the metal suffers in physical properties. Practically any fuel which will maintain a temperature of 1600 degrees Fahr. in the furnace is satisfactory. Some foundrymen caution against heating too rapidly, but I have used oil as a fuel in a 5000-pound furnace which reached 1600 degrees Fahr. in 10 hours, but the castings in the boxes, packed in mill scale, did not attain 1540 degrees Fahr. (their maximum temperature) for 32 hours after starting. It is interesting to plot a cooling curve, comparing the temperature of the castings with furnace temperatures. The furnace may cool at an average uniform rate of 10 degrees per hour while the castings cool at an average rate of 8 degrees per

hour. The slope of the castings temperature curve will be closer to the horizontal than the furnace temperature line on account of heat evolution from the precipitation of proeutectoid graphite. From 1350 degrees Fahr. to 1200 degrees Fahr. the eutectoid graphite precipitation causes a "hump" in the castings curve, but from 1200 degrees Fahr. down, the two lines are parallel and close together. The rates of cooling vary under different conditions. For instance, if sand is used as a packing material, the cooling of the castings will be slower.

Electric Furnace Malleable

The electric furnace would seem to be an ideal medium for melting malleable iron. The high temperatures available will give sufficient fluidity to pour the thinnest castings with low carbon metal. The temperature of the metal in the furnace is sufficient to cause carbon absorption, so that a weighed quantity of coke or broken electrodes can be thrown into the metal, and the exact carbon increase figured. If necessary, the metal can be held in the furnace and a quick analysis made before tapping, as in open-hearth steel practice. However, the author has had considerable experience in melting malleable iron in arc-electric furnaces and believes that they are not practicable, except in special cases, because of annealing difficulties. It should be noted that arc-electric furnaces are mentioned, as I have had no experience with malleable iron in induction furnaces. My experience has indicated that electric furnace iron requires a furnace cooling speed of 5 degrees Fahr. per hour or under, to obtain complete annealing. It might be mentioned that with very thin castings, using a slightly oxidizing packing, results, comparable in ductility with normal malleable, may be obtained because of the aid given by partial oxidation of the carbon, which is similar to European practice.

I have used acid and basic furnaces of different types, and many variations in analysis without overcoming this slow annealability. Lowering of Mn. to correspond to the low S. of basic furnace practice, or raising the S. to give a better Mn.-S. ratio had no noticeable effect. I have tried almost every conceivable combination of Si. and C., but have never been

able to produce a free annealing metal. I have also used different annealing methods without being able to shorten the annealing time. The work of Honda and Murakami*, indicating that graphitization depends on the catalytic action of CO and CO_2, led me to suspect that reducing conditions in the electric furnace may have had some effect on the metal. Mill-scale has been added and agitated just before tapping, without any improvements. Exhaustive metallographic tests have thrown no light on the cause of this annealing property, but it is believed that the high temperature of the electric arc (about 6300 degrees Fahr.) is responsible. Gray iron undergoes a distinct hardening effect when melted or refined under the electric arc, therefore it is reasonable to believe that this mysterious hardening influence is present in electric furnace malleable and resists graphitization. This hardening effect is permanent for electric furnace malleable scrap used with pig iron in oil furnace malleable heats, produces castings which are not free annealing. It must be realized that malleable cast iron is a sensitive, delicately balanced material, and the fact that cupola malleable has different annealing characteristics than air-furnace malleable, makes it not so surprising that electric furnace malleable differs also.

Conclusion

Although high quality malleable iron can be produced in small quantities, as herein outlined, the average foundryman should think twice before going into this field. Serious complications have developed in most shops where an attempt has been made to load up the gray-iron foundry superintendent with brass, steel, or malleable iron. The gating problems of malleable iron are much closer to steel than to gray-iron, and the manufacture of malleable is a diversified industry in itself. In making small quantities the costs are high and trouble is liable to be encountered unless an expert is on the job, particularly at the start. Although the arc-electric furnace seems ideal for the melting of blackheart malleable, foundrymen should go slow on this medium until more research has been done towards cutting down annealing time.

*Iron and Steel Institute of Great Britain, No. 2 (1920).

In conclusion, the author wishes to acknowledge his indebtedness to G. K. Elliott, for valuable suggestions and assistance in this work.

Checking Malleable Foundry Scrap

By E. D. Halsey, Terre Haute, Ind.

One of the most baffling problems that the foundry has to contend with, is that of scrap. While every foundryman is familiar with the accepted causes and the practice of overcoming the same, there is yet a great deal to be learned in regard to these causes before we can hope to reduce this figure to a point where it will not be a vital factor in any well regulated shop. Much, however, can be accomplished along this line by close co-operation among the different foremen and departments and an accurate and efficient system used to check and handle this scrap.

At the foundry with which the writer is associated a system has been worked out that has proved itself to be indispensable in informing the foremen and the office as to just what the situation is in regard to scrap, at all times.

It seemed that, at this foundry, whenever there was an excessive amount of scrap there was always a tendency to lay the blame on some other department, commonly known as "passing the buck." Other serious conditions that were found to exist were, scrapping many castings that could be salvaged by an extra operation, passing castings that should have been scrapped in the hard iron, and thereby burdening the shop with the expense of annealing and handling these castings, and shipping castings to customers that should have been scrapped in the shipping department.

Committee Analyzes Cause of Rejected Castings

In order to contend with these conditions, a committee, known as the scrap committee was formed. This committee is composed of the superintendent, assistant superintendent, all foremen, and the production manager.

The duties of this committee are: to inspect all scrap, salvage all castings that can be saved by some extra operation, such as grinding, etc., and to determine the cause of, and to suggest any methods for overcoming the scrap.

The committee meets at 8 o'clock every morning to go over the hard iron scrap. This scrap has already been divided according to foundries and sub-divided according to molders. The members of the committee go over these piles, throwing aside any castings that are to be salvaged and inspecting the castings to determine just why it was scrapped and whether or not there is any method of correcting the trouble. In this way the committee determines if the evil can be corrected by regating the job, by increasing the size, or changing the location of the feeders, by chilling, etc.

Being a member of this committee gives the production manager an excellent opportunity of keeping in close touch with all jobs, determining which jobs it will be necessary to keep in the sand longer than anticipated, in order to make up for the excessive amount of scrap.

At the 8 o'clock meeting the production manager gathers all the data for making out his daily scrap report, which report will be discussed in detail a little later on.

Molders Inspect Rejected Castings

At eight-thirty the molders are called in and allowed to inspect their own scrap with their foundry foremen. At this time it is determined whether the scrap was the molder's fault or due to some foundry condition beyond the molder's control. In case of the latter, the molder is given credit for all scrap for which he is not responsible.

Production Manager Tabulates Data of Defective Castings

The scrap report, already referred to, is a report made out by the production manager, on all jobs running over 10 per cent scrap. This report, however, has in addition several other very valuable figures. The report is divided into three parts, one for each foundry. Immediately below the foundry number, is given the number of molders that were working that day, the

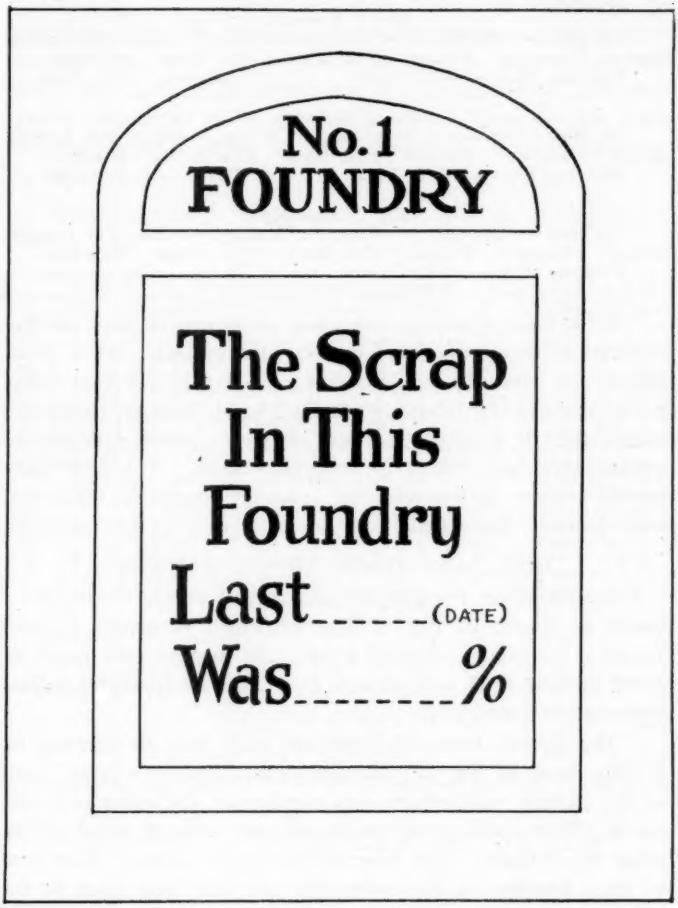

FIG. 1—SCRAP BOARD POSTED IN FOUNDRY WHERE MOLDERS CAN SEE THE RECORD MADE BY THEIR DIVISION IN COMPETITION WITH OTHER FOUNDRIES OF THE PLANT

average number of pounds per molder and the average weight per casting. The report is made out as follows:

Production Manager's Report

Molders Scrap Date

No. 1 Foundry

On Duty——Molders. ——Lbs. Per Molder. ——Lbs. Per Casting.

Bench Customer Pattern Pcs. Made Pcs. Scrap Remarks.

Previous Day———Per Cent Today———Per Cent

No. 2 Foundry

On Duty——Molders. ——Lbs. Per Molder. ——Lbs. Per Casting.

Bench Customer Pattern Pcs. Made Pcs. Scrap Remarks.

Previous Day———Per Cent Today———Per Cent

No. 3 Foundry

On Duty——Molders. ——Lbs. Per Molder. ——Lbs. Per Casting.

Bench Customer Pattern Pcs. Made Pcs. Scrap Remarks.

Previous Day———Per Cent Today———Per Cent

Total———Per Cent.

With these figures a very close check can be kept on production efficiency in the foundry. Immediately below these figures, are given all the jobs that run over 10 per cent scrap, listing them in the following manner: bench number, customer's name, pattern number, number of pieces made, number of pieces scrap, and causes of scrapping same. The last figure on the report is the total per cent of scrap by weight in each foundry, individually, and also the total of all foundries.

Scrap Board Arouses Interest of Molders

From this sheet the per cent of scrap is posted on the scrap board as shown in Fig. 1, one of which is placed in each foundry for the purpose of getting the men to take more interest in their work and perhaps to stir up a competitive feeling between the foundries.

The figures from this sheet are also used in drawing up a scrap curve of Fig. 2. This curve is drawn on a large board in the pattern vault where any member of the committee may see it. This curve shows graphically the exact position of the scrap at all times. One copy of this scrap report is then sent to each member of the committee and one copy goes to the office.

Following Up Causes of Rejections

The assistant superintendent checks these reports, with each foundry foreman, daily, in order to determine whether or not the suggestions of the committee are being carried out and

also to make any new suggestions, going to the molder's bench if necessary to try to discover some method of improving the condition. Any jobs that appear on this report for more than two or three days steady are given special attention at this time. The assistant superintendent also checks up on all broken castings shown on the scrap sheet, trying to discover the cause of breaking and trying to find some method of overcoming the same.

This committee meets again at 1 o'clock to inspect all

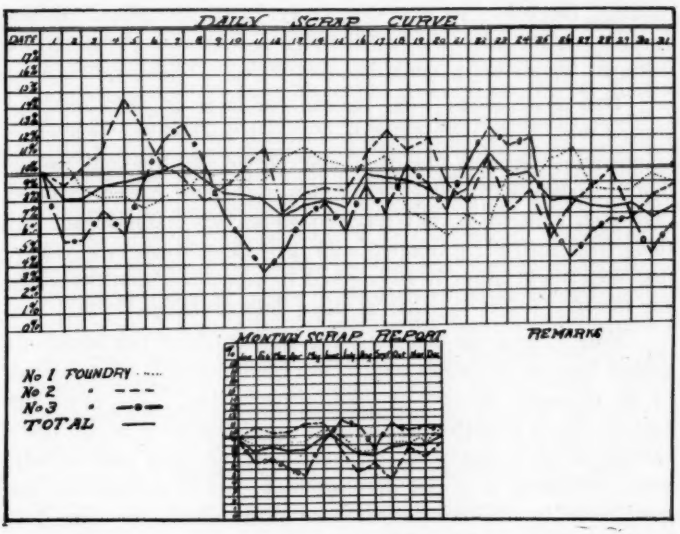

FIG. 2—DAILY SCRAP CURVE WHICH IS POSTED IN PATTERN VAULT FOR INSPECTION OF THE MEMBERS OF THE SCRAP COMMITTEE

shipping room scrap. All castings that are to be salvaged are laid aside and then the committee decides whether the casting should have been scrapped in the hard iron or the defect has developed after the castings have entered the anneal. In case of the former, the attention of the hard iron foremen is called to these jobs and he is expected to see that it does not occur

again. In the latter case, the committee determines if the castings were scrapped due to warpage in the anneal, to scale, poor milling, grinding, drop hammer, etc., and endeavors to find some way of overcoming the same.

Customer's Rejections Analyzed

The only other duty of this committee is to inspect all scrap returned from customers and determine whether it is their machine shop scrap or our own scrap. In the first case the matter is taken up with the customer while in the latter case the inspectors are called in and instructed to examine these castings carefully, so that the defect will be noticed in the future. At the same time all castings are separated, that can be salvaged by an extra operation.

This system has been in use for over a year and has proved itself to be very valuable in that it necessitates very close co-operation between the men and proves out the old saying that "Two heads are always better than one" and it has been found that each department has received some very valuable suggestions from men not connected with their department in any way, that they might never have received if it had not been necessary for the men to get together at these daily meetings.

Note. Since the completion of this article, it has been suggested that an objection might be raised that this system took up an excessive amount of the foremen's time. Therefore the author wishes to state that the total time consumed in the functioning of this committee is never over an hour and a half, while ordinarily it is not over an hour, and it is felt that the good done by the committee more than offsets the time lost by the foremen.

Report of A. F. A. Committee on Specifications for Malleable Castings

The last report of your committee on malleable iron castings contained the announcement that at a joint meeting of the American Society for Testing Materials, committee A-7 and this committee, it was decided to recommend an alteration in the dimensions of the tensile test bar; an increase in tensile requirements and a very slight addition to the text. These recommendations were presented and put into effect by the American Society for Testing Materials at their meeting on June last through their tentative specification, known as Proposed Revised Standard Specifications for Malleable Castings, serial designation: A47-22T. In this tentative specification the ultimate strength per square inch has been raised from 45,000 to 50,000 pounds; the elongation from 7.50 per cent to 10.00 per cent in 2 inches; while the tensile test bar has been shortened from an overall length of 12 inches to 7½ inches; the gage length including fillets from 6 inches to 2½ inches, the diameter gage length and grip ends remaining the same. You are further advised that a joint meeting of the American Society for Testing Materials committee A-7 and this committee has been called for the afternoon of May 1 in order to consider, and if thought expedient, approve any suggestion that may be offered at that time.

W. R. Bean
John Gelder
Rupert A. Nourse
A. L. Pollard
A. E. White
Enrique Touceda, *Chairman*

Briquetting of Brass Turnings

By F. L. Wolf, Mansfield, O.

As we operate our own machine shop, our foundry has a continuous influx of brass borings and turnings to be remelted. Anyone with experience along this line will tell you that it is expensive to handle and melt these chips, and this question of expense confronted us when the idea of a briquetting machine was directed to our attention. The theory of this machine was excellent. By some adaptation of the hydraulic press we could compress our borings and turnings into briquettes which could be used practically the same as brass ingots. Theoretically this would greatly facilitate handling and melting. In addition, a tremendous amount of money could be saved. We decided to buy one of these machines, but our experience gained from the use of this machine was discouraging. After a survey of the following data you can draw your own conclusions as to whether the results obtained were satisfactory.

SUMMARY

After experimenting with a briquetting machine for several months, we found no economy in melting. We found it rather more convenient to carry briquettes up to the furnace than to carry loose chips but the breakage of briquettes in the furnace was considerable. The data of Table 1 were obtained from ten specific heats with the use of briquettes and without the use of briquettes. All handling and furnace conditions were practically the same.

Table 1

Comparison of Results, Using Loose Turnings and Briquetted Turnings

Test No. 1	No. heats	Total metal pounds	Pounds poured	Pounds loss	Pct. loss	Metal Skim and slag	Metal recovered from slag	Total recovered	Net loss	Pct. loss
Loose borings	5	2608.5	2426.5	182	7	142	84	2510.5	98	3.75
Briquettes	5	2603.5	2419.5	184	7	148	88	2507.5	96	3.7
Loose borings	5	2610	2450	156	6	180	62	2516	94	3.6
Briquettes	5	2610	2429	181	6.9	193	78	2507	103	3.9

No difference was noted in the physical properties of the alloy melted nor in the appearance of the castings upon inspection.

INVESTIGATION

Equipment

Our experiments were carried out with a briquetting press purchased from the General Briquetting Co., a manufacturer making such a press as a regular line of product. The press consisted of a hydraulic cylinder and end block which is connected by means of two side rods. It was provided with a 4-inch diameter mold, 9 inches in length; stroke of ram, 24 inches; diameter of hydraulic piston, 10½ inches; retrieve ram, 4-inch diameter; and a working pressure 3000 pounds to 3500 pounds per square inch.

Time of Melting

The metal was melted in a Schwarz furnace, the average charge being about 540 pounds. In Test No. 1, we used 150 pounds of borings per heat, the remainder of charge consisting of scrap and prime metal. It took about 50 minutes to get the metal up to the proper pouring temperature and no difference in time of melting was noticed whether the boring were charged loose or in briquettes. In Test No. 2, we charged 225 pounds of borings per heat and it then took about 65 minutes to bring the metal up to the pouring temperature. Again there was no time saved by the use of briquettes.

Melting Loss

In order to determine the net melting loss, we weighed our pouring ladles—which hold about 100 pounds of metal—before having been filled with molten metal and after. The difference was added to the total pounds of metal poured from the heat. The skimmings and slag were run through our concentrating plant and the metal recovered. The melting loss, whether we charged loose borings or briquettes, was practically the same.

Handling of Borings

If the convenience in carrying briquettes up to the furnace was the only item to be considered, the briquetting machine

would now be in use in our foundry instead of on the scrap heap. Unfortunately this is not the case. After storage in our foundry for any considerable length of time the briquettes would develop cracks and distintegrate. After charging into the furnace, there was considerable breakage of briquettes. This was no doubt due to the air pockets in the briquettes expanding, the internal pressure thus set up disintergrating briquettes. According to the manufacturers of the briquetting machine, this was not supposed to occur but even by following their instructions implicitly, we could not prevent the troubles.

Physical Properties

Considerable experimenting has been carried on in our foundry to determine the effect of charging various combinations of prime metal, scrap (gates, sprues, etc.) and chips. We have taken this matter up more in detail in another article.* We have found that any reasonable combinations of prime metal, scrap and chips can be used providing there are not too many detrimental impurities present such as sulphur, iron, etc. and that proper foundry conditions have been maintained. In our foundry we have been obtaining consistently good results by using any number of combinations. We aim to use up our scrap just as fast as it is received in the brass foundry and we make up our mixes accordingly. Briquetting the borings absolutely made no difference in the physical properties as compared to using loose borings as we maintained the proper furnace conditions while melting and poured at the proper temperature.

CONCLUSION

As above mentioned we are drawing no conclusions. We are merely stating the facts as we found them, hoping that they will be beneficial to the foundry profession in general.

*"Some Information on the Proper Melting and Pouring of Brass and Bronze." F. L. Wolf and Wm. Romanoff, *Transactions*, A. F. A. Vol. 31, pp. 355.

Discussion—Briquetting Brass Turnings

Chairman G. H. Clamer.—That might be called rather a negative result, but it is right in line with our own experiences in the use of briquets. I think the briquet manufacturers if they are successful, will have to come to a very small briquet. It is hard to get the heat through the large briquet and the loss is just about as great as when the turnings are used without briquetting. We have had some little experience in melting briquets of a very small size, and if they can be produced economically I think that is the solution. But, of course, there is quite a cost involved, and the question of the cost of the briquets is worth while in the consideration of the saving effected.

Mr. Mortimer.—I would like to ask Mr. Romanoff how they handle their turnings. We have quite a considerable number to handle, and it is quite a problem at times.

W. Romanoff.—Our turnings come to the brass foundry and pass through a magnetic separator, and we figure our formulas for the amount of borings and turnings received into the foundry, and also the chips, and we operate a concentrating plant. We figure our formulas so we can just take care of the amount of borings received. In other words, we really plan to have excess borings. We don't want to use them all up as they come in. When times are slow and we don't have to use our big electric furnaces, we run it at night and melt our turnings into small ingots, and we have enough storage space to take care of them.

Mr. Mortimer.—That is hardly the question I asked. The question was this: How do you melt them in your furnace when you are charging them? Do you charge them in loose?

W. Romanoff.—We charge them loose.

Mr. Mortimer.—Do you have soda water to contend with in your turnings—any cutting compounds?

W. Romanoff.—Occasionally we do.

Mr. Mortimer.—Do you have any trouble with the fumes?

W. Romanoff.—Aside from the fumes given off at the beginning of the heat, we have no trouble. After it becomes melted we don't have any trouble at all.

Mr. Ive.—In the previous paper you said you made tests up to 25 per cent of turnings. Can't you go up to 50 per cent without much trouble? Have you made any experiments along that line?

W. Romanoff.—We have made experiments as high as 40 per cent, and we found we didn't have to use that much. We had a little trouble in melting by using 40 per cent of borings. As far as the physical properties were concerned, we didn't have any trouble; in the melting down was where we had some trouble.

Notes On The Proper Melting and Pouring of Brass and Bronze

By F. L. Wolf and Wm. Romanoff, Mansfield, O.

We not only anticipated but we have actually realized in the preparation of this paper the difficulty in relating experiences in a modern brass and bronze foundry that will appeal to non-ferrous foundrymen in general. Experiences are too diversified to simplify this problem. Difficulties which the small foundry might contend with daily are likely to be only periodical in the large foundry with its modern equipment and research. On the contrary the small foundry with its personal contact might be able to overcome such troubles which tend to disturb the equilibrium of its larger and more unified competitor. How can one expect to interest all foundrymen in a comparison between the electric and oil or other fuel fired furnaces when the nearest approach of a small foundryman to an electric furnace is to probably see one at the Foundrymen's Exhibit? His worries concern more the accumulation of enough money to meet his payroll than to buy the expensive electrical melting equipment. Other foundry problems which we mention in the body of this paper might also be considered along the same line of comparison. We have however attempted to discuss certain phases in the regular foundry routine which, while they may not entirely appeal to all foundrymen, we feel will give a certain amount of information that will be invaluable to the foundryman, whether his business be large or small. The information given is founded upon good, sound theories applied practically. We submit our ideas for your attention. Following is the order in which the subjects are discussed:

1. Pouring temperatures.
2. Comparison of melting furnaces.
3. Mixes.
4. Fluxes.
5. Deoxidizers.

Pouring Temperatures

We can not think of any single operation in the foundry that has more influence in determining the quality of the ultimate finished product than that of pouring at the proper temperature.

If, in order to obtain a better metal, you took the necessary steps, while melting, to see that your molten metal was properly covered and that it was not permitted to "soak" in the furnace; you saw that the furnace had the proper atmosphere, whether it be oxidizing, neutral or reducing; you used any type of furnace, whether it be open-flame, crucible or electric; you used any mixture of scrap and virgin metal; the results of all these precautions would be offset if the metal were poured at an improper temperature. This statement may at first thought appear to be ambiguous, but upon further analysis you will no doubt agree. Or better still, a trial will surely convince you.

In our brass foundry we manufacture valves, line material for electric railways, mining material, etc. To show the effect of pouring at the wrong temperature, let us consider the case of pouring one of our alloys. In this particular case we used 50 per cent virgin metal and 50 per cent gates and sprues from our own foundry. Merely a difference of 100 degrees Fahr. between the proper temperature, which we will designate A and the improper temperature, which we will designate B gave us the following difference in physical properties:

Temperature	Tensile strength in pounds per square inch	Per cent Elongation in 2 inches	Per cent reduction of Area
A	27550	14.6	15·3
B	16316	7.5	6.4

The same furnace conditions were maintained in each case. In fact we poured A and B from the same pot of metal. Test bars and castings were poured at temperature B and the remaining metal chilled down with gates and sprues to temperature A and poured. And still we hear of salesmen selling a cheaper grade of brass products accentuating the fact that their material is as good as their competitors because it has the same composition. To us, it is amusing. It could be likened to

comparing two different makes of automobiles because their bodies happened to have the same color, workmanship to the contrary.

The above results are consistent with theory and with the results we have always obtained in practice in our foundry since the introduction of temperature control. Molten metal has a tendency to absorb gases, the higher the temperature, the more gases absorbed. Upon cooling these gases are given off. When pouring a casting, the outer surface solidifies first. Therefore, the higher the pouring temperature the more gases entrapped between the crystals of the metal and necessarily the less dense and more brittle it will be.

When our castings leave the foundry, they are sent back to the brass casting department where the castings are cut off from the gates, after which they are rough ground and sandblasted. They are then inspected and divided into the following groups: misrun, dirty, shifted and good castings. Shifted castings are due to faulty molding or pattern equipment and will be eliminated from this discussion. We find that the percentage of dirty castings is greatly increased when poured at too high a temperature. This is accounted for as follows: If the metal is excessively hot, the temperature is such that it retains the oxides and other impurities in a fluid or plastic condition. When pouring the metal in such condition, the surface of the metal in contact with the mold solidifies, thereby entrapping oxides and impurities and causing "dirty" castings. If the metal is chilled to proper pouring temperature the oxides and other impurities are permitted to solidify and due to their lower specific gravity float to the surface. The slag can then be readily skimmed off. If the metal is too hot, it also has a tendency to "eat" into the sand, causing rough, dirty castings. On the other hand pouring the metal too cold, is likely to cause "misruns".

To give a further illustration of the effect of pouring at too high a temperature, we will cite the case of pouring another one of our alloys. In this particular case, we used 50 per cent of scrap and 50 per cent of virgin metal. Again, as in the previous

alloy, there was only a difference of 100 degrees Fahr. between the higher or improper pouring temperature B and the proper pouring temperature A, with the following difference in physical properties:

Temperature	Tensile strength in pounds per square inch	Per cent Elongation in 2 inches	Per cent reduction of Area
A	35800	27.6	32.9
B	25475	14.7	18.7

We might sum the entire question of pouring temperatures into the statement that when metal is overheated or permitted to "soak" in the furnace for too long a time, there is gasification of the metal taking place instead of an oxidation which is generally supposed to be the case. That probably accounts for the fact that upon chilling an overheated metal, it practically returns to its normal state. In passing, we might add that the pouring temperature should be as low as possible, consistent with the size and shape of the castings in order to obtain the best possible physical properties.

Comparison Of Melting Furnaces

There is always a question as to the quality of metal produced by different types of furnaces. In our brass foundry we operate three types of furnaces, the open flame type as represented by Schwarz furnaces, the crucible type as represented by Steel-Harvey furnaces and the electric as representd by an indirect arc type furnace. As the management insists that everything be subservient to quality in the manufacture of our products, we have experimented extensively to determine whether one or more of these types of furnaces should be eliminated from our foundry due to producing an inferior grade of metal. At this writing we have also installed an electric furnace of the induction type, but, as yet, we have not enough data to allow this to enter into a comparison with the other types of furnaces.

Costs

Let us first consider costs. This is the standard upon which the majority of concerns base their conclusions as to whether any equipment or process is to enter into production.

It is especially prevalent among the smaller concerns. But as this is not a discussion of business economics we will get to the point in question. At our plant the cost of melting one ton of metal in electric, Schwarz and Steel-Harvey furnaces is as follows:

*Electric	$22.99
*Schwarz	20.38
*Steel-Harvey	17.86

This comparison includes fuel, labor, lining, melting losses crucibles and all other incidental items necessary to melting metal, and was compiled during a long period of time In addition the and all other incidental items necessary to melting metal, and was compiled during a long period of time. In addition the slag recovery is also included as we operate a concentration plant. Space does not permit us to itemize the individual costs.

Quality

A comparison of the quality of the metal melted in the above mentioned three types of furnaces will prove interesting as well as surprising. In fact it is contrary to the opinion which is almost universally prevalent among foundrymen about the decidedly superior metal obtained in an electric furnace as compared to other fuel fired furnaces. We direct your attention to the following comparison:

Furnace	Ultimate Tensile strength in pounds per square inch	Per cent Elongation in 2 inches	Per cent reduction of Area
Electric	28587	18.1	18.7
Schwarz	27655	14.7	14.0
Steel-Harvey	26800	16.1	15.2

While the advantage seems to be slightly in favor of the electric furnace, we think it is so small that it need hardly be considered. But we must admit that the electric furnace is by far the more fool-proof. Proper furnace conditions as well

*Power for electric furnace has been figured at the rate of 2 cents per K. W. H. Fuel oil for Schwarz and Steel-Harvey furnaces at 6 cents per gal.

as pouring temperatures must be maintained in order to obtain as good a quality of metal from the Schwarz and Steel-Harvey as from the electric. Wherever possible, comparisons were made upon the finished castings poured from the various furnaces and any difference in quality was hardly noticed.

Another phase which is coming into consideration, more and more every day, is that of zinc fumes. From a humane standpoint this must be considered. If you have ever worked in a brass foundry during the winter time with all the doors and windows closed tight, you will readily agree as to the necessity for considering this feature. Zinc "shakes" are not pleasant. The electric furnace with its sealed melting chamber is far superior in eliminating this evil. We might add that with labor at a premium as at present, working conditions should be such as to keep the minds of the employes in a contented state and the electric melting furnace is a step in the right direction.

Mixes

Every foundry that operates a machine shop has a continuous influx of brass borings and turnings to be remelted. In addition there are the gates and sprues which have been cut off from the castings. As near as possible it should be the aim to consume all of this scrap material in the foundry in the same proportion as it is received, thus avoiding any unnecessary accumulation. This greatly reduces the cost of the raw material as compared to what it would be if all virgin metal were used in the manufacture of your castings. We, therefore, had to do considerable experimentation to determine whether this scrap would be detrimental to the metal, and if not, in which proportions it could safely be added. In carrying out these experiments, all melting and pouring conditions were maintained as uniformly as possible, the only variations being in the combinations of scrap and prime metal used.

In the manufacture of one of our bronze alloys we used three combinations of metals, one consisting of all prime metal, one of equal parts prime metal and scrap, consisting of gates and sprues, and one containing all scrap, consisting of gates and sprues. The following results were obtained:

MIX Per cent Prime	Per cent Scrap	Ultimate tensile strength in pounds Square Inch	Per cent Elongation in 2 inches	Per cent Reduction of Area	Brinell Hardness
100	0	37050	23.4	21.2	72
50	50	34500	21.1	21.0	68
0	100	38566	22.9	21.1	68

While there is a slight reduction in the ultimate tensile strength when using half scrap and half prime metal, still there is no radical difference. The elongation, reduction of area and Brinell hardness are practically the same using any of the combinations.

In another case, we used combinations of prime metal, scrap, such as gates and sprues, and composition ingot metal purchased from various smelting and refining companies. These were used in the melting of one of our brass alloys. Composition ingot is usually obtained by the refining of concentrates, borings, turnings, etc. The following results were obtained:

MIX Per cent Ingot	Per cent Scrap	Per cent Prime	Ultimate Tensile Strength In pounds per Square Inch	Per cent Elongation In 2 Inches	Per cent Reduction of Area	Brinell Hardness
0	33	67	24450	14.3	13.0	52
25	27	48	23841	13.2	9.4	54
50	33	17	23266	12.2	10.1	50
75	0	25	26800	16.1	15.2	48

There is some variation in the reduction of area but the remainder of the results are fairly consistent.

We melted still another one of our brass alloys using 25 per cent of borings in one case, the remainder being ingot, scrap and prime metal and in another case we eliminated the borings. Following are the results obtained:

Mix	Ultimate Tensile strength in pounds per square inch	Per cent Elongation in 2 inches	Per cent reduction of Area
With borings	27655	14.7	14.0
Without borings	28825	16.9	17.6

These results are again consistent.

In the combinations of scrap and prime metal used, one thing must be taken into consideration, and that is the fact that when all other conditions are equal, there is a greater

shrinkage in the castings the more prime metal used in the mix. Several theories have been offered by others to account for this. We offer no explanation. We know that it is a fact.

The sum and substance of the whole subject of mixes can be simmered down to the following: Any reasonable combinations of prime metal and scrap can be used providing there are not too many detrimental impurities present such as antimony, iron, etc. and that proper foundry conditions have been maintained. In our foundry we have been obtaining consistently good results by using any number of combinations. We aim to use up our scrap just as fast as it is received in the brass foundry and we make up our mixes accordingly.

Fluxes

We do not wish to put ourselves in the position of belittling any flux. Probably we do not know how to use a flux. In our investigations, we merely carried out implicitly the written instructions of the flux manufacturers. And in each case the physical properties were no better with the use of a flux than without. All other foundry practices were the same in both cases. We experimented with two fluxes of national reputation, or rather, two fluxes that are nationally advertised. Then we stopped. We were convinced, but in a disappointing way. After reading the lurid advertisements of the different fluxes, we expected considerable improvement in our metal upon usage. Probably we expected too much. It may be good business psychology to tell your customers that in the manufacture of your product you use the best and highest price fluxes obtainable but psychology never prevented "leakers" in valves nor increased the toughness of a trolley wheel.

In the melting of our brass or bronze alloys, we melt the red metal first and when molten, we add the white metal. About 5 to 10 minutes later, we pour. In the interim between adding the white metal and pouring, we add a little sand as a covering to prevent as much volatilization of zinc as possible while the metal is molten. That is the only flux that is used in our foundry.

We might add that if the foundry uses scrap of unknown quality and the melting conditions are questionable, there might

be some advantage in using fluxes as scavengers. If your foundry practice is under control and you are using a high grade scrap of known analysis, we use nothing but our own domestic scrap in our foundry, there is no particular advantage in using these high priced fluxes.

Deoxidizers

We have always obtained good results by the use of deoxidizers but like most good things an excess may often prove deleterious. We feel that in general, the choice of the specific deoxidizer depends a good deal upon the individual user in which psychology plays a very important part. Without belittling any of the other standard deoxidizers on the market and appreciating their specific worth to the industry, we have found phosphor copper containing about 8 to 10 per cent phosphorous to be the most practical in our foundry. We add a fraction of an ounce per pot of metal, containing 100 to 150 pounds, and it is added just before pouring. But as we hark back to occasions when an excess of this "good thing" was added, we can recollect the following grief: the metal became so active it "cut" the sand in our molds causing rough, dirty castings; castings deteriorated due to the formation of the hard brittle Cu_3P compound; in the high lead alloys the lead segregated to the outer edge of the castings ruining appearance, where this property is essential, and causing porous metal.

Aluminum as a deoxidizer should never be used in an alloy containing lead as porousness is almost certain to occur and if the alloy is to be used to withstand any internal air pressures, it would spell certain ruin.

Silicon in a brass containing lead should also never be considered as a deoxidizer. In fact it should never be considered in any copper alloy where electrical conductivity is one of the properties desired.

In passing, we might state that the writers have always found the use of a deoxidizer to be desirable but its choice and use must be tempered with good judgment or the good judgment of your customers will eventually decide for you by choosing another foundry to manufacture their castings.

Conclusion

We hardly feel that in this short discussion we have covered all of the minor details that would occur in one's experiences in a modern brass foundry, but by accentuating the major problems as has been our endeavor, there is a possibility that the minor problems might thus have been taken care of. We have tried to emphasize the following points:

1. The pouring temperature should be as low as possible, consistent with the size and shape of the castings.

2. With proper foundry conditions, practically any type of melting furnace can be used to obtain a good quality metal. The cost of melting varies, dependent upon the type of furnace. From a humane standpoint we prefer the electric furnace due to its lower melting losses thus eliminating a large amount of zinc fumes.

3. Practically any reasonable combination of prime metal and scrap such as gates, sprues, borings, turnings, etc. can safely be used provided they do not contain any detrimental impurities.

4. Good metal can be obtained without the use of fluxes if proper furnace conditions are maintained. If not, fluxes might be of value.

5. Deoxidizers have been proven worthy. The kind to use depends upon the kind of metal melted and the prejudices of the users for or against certain ones. This should be tempered with a fair amount of good judgment.

Fortunately for the industry, we are disregarding more and more the traditions which have been prevalent among foundrymen for decades. We are beginning to realize that there is nothing supernatural about the workings of a foundry and that the supposed mysticisms which have been handed down from fathers to sons and they in turn to their sons and so on down the line are purely and simply imaginative and things of the past. Foundrymen realize today that they can account for practically everything that occurs in a foundry. They realize today that practically all of the processes of manufacture in a foundry are founded upon good sound principle and theory and

upon this foundation have they built an industry that is gaining its deserved recognition from the world of science, art and business.

Discussion—Notes on Pouring of Brass and Bronze

Chairman G. H. Clamer.—The fact is, gentlemen, there are good fluxes and bad fluxes; there are times when fluxes should be used and times when it is not necessary to use them, and the trouble is that generally among the foundrymen they do not know those fundamental facts. Just very recently there has been a movement afoot to organize a committee of the American Society for Testing Materials on fluxes and flux alloys. This committee will no doubt undertake the investigation of various fluxes and fluxing materials on the market and the foundrymen will finally be put in possession of the underlying facts concerning fluxes and fluxing materials.

Fluxes are used in metallurgical operations, in the reduction of ores which usually are oxides, to their virgin metals and with alloys that are oxidized or spoiled in the furnace and which require deoxidation to bring them back to their normal condition. In such cases, of course, deoxidizing agents are desirable.

It is also desirable to bring solid nonmetalic particles to the surface in order to skim them off.

Mr. Comstock.—I would like to suggest that the results of the tests of tensile strength would be more valuable if the number of individual test bars were given. There were only three or four bars to get the result given and the difference might be insignificant, but if there were twenty or twenty-five bars tested for each result, I think the difference in the averages would be much more important.

I would also like to state my experience with silicon in copper for high conductivity castings. I know several foundries where very excellent conductivity results were obtained in copper castings with the proper use of silicon. I think the condemnation of silicon for that purpose is not warranted in the paper.

Chairman G. H. Clamer.—I think in the case of silicon, it is very much the same case as stated regarding the use of the phosphoric copper, it is more detrimental to use too much than not to use any, or too little, and it has been my experience that silicon, if used in the proper proportions does make a fairly good conductivity casting. I believe, however, there are other methods of making high conductivity castings that are superior to using silicon.

H. M. St. John—On page 359 cost comparisons between types of furnaces are given, including the electric, and on the previous page the statement is made that the electric furnace used in this particular application is not of the variety, ordinarily referred to as the "indirect arc" type; and further, I am quite sure that the general experience of people using the electric furnace, those types commonly used, including both the indirect arc and other types, does not agree with the comparisons given. I think that should be direct arc.

Mr. Olson.—I don't believe it makes much difference what type of furnace you have, if you handle it the way it should be handled. We feel it is possible to get sound castings out of the open flame furnaces.

N. K. B. Patch.—In connection with the subject of fluxes, I just want to corroborate the remarks along those lines. The use of fluxes is purely a chemical action, and not a "cure-all" for all the troubles of the brass foundry. It is simply a question of using them intelligently where a chemical reaction is desirable to dissolve the oxides by some suitable fluxing agent, and where chemical control is in operation on the melting practice. There are times when a flux is desirable and is almost necessary; as outlined in the paper, where the metals are all virgin metal or high-grade scrap, it is very probable that a flux is hardly necessary. In fact, if the furnace atmosphere is properly con-

trolled and the metal is of the character that has a small amount of material in it to be dissolved by the fluxes, there is practically no need of flux. Therefore, one foundryman's experience with the use of flux would be of one kind, because his conditions are the kind that need the flux, and the conditions of the other foundryman would be such that the operation will be carried on satisfactorily without it.

Mr. Robertson.—I might say we use a Schwartz furnace for a pressure casting, and I generally get my metal up above 2200 degrees Fahr. Sometimes it goes up to 2400. The only thing I do is put in the phosphorus copper and pole it. I think I have pretty fair results. That is in an open-flame Swartz furnace, melting 85-3 and 88-10-2 and metal with up to 20 per cent lead. I don't use any flux at all.

R. L. Binney.—I want to question what is said about the pouring temperature being so low. Of course, we agree absolutely with that, but we want to know this: As the analysis changes, is there not a distinction there? Would you cast 88-10-2 the same as 80-10-10? We find there is a difference in there from our experience, but we have no data coherent enough to prove that it is, although we have files that are rather specific for the past ten years.

We want to know, too, about overheating metal before it is taken from the furnace. We can't prove that the metal is not so good after it has been superheated. I see there is a loss there due to volatization, but in our experience we find that we can't foretell that condition. We have taken the metal and run it up to 2400 and 2500 degrees Fahr. and it has come out remarkably good. We have found variations and oxides and all diseases of the metal when it has been low and when it has been high, but we can't find any one to give us specifiic information, and I wish some one here would enlighten us so we can have a set of rules.

W. Romanoff.—In answering Mr. Binney's questions, the first one refers to the method of measuring the temperature of the molten metal. In our foundry we are using the Hoskins pyrometer, which we calibrate once a week, and in that way we

are able to get pretty accurate results, as far as temperatures are concerned.

The second question refers to analyses, whether we should pour one metal hot if it contains whatever is given in the analysis. In the first place, the temperature for pouring a metal all depends on the section you are casting, and also the gating of your casting. If we have a larger gate we can pour the metal colder. If we have a small gate there is too much of a chance of getting misruns and we must pour metal hot. I don't know if that covers the point he refers to or not.

R. L. Binney.—I took it for granted that the gating and the sections were considered. Even then, should the analysis of the alloy affect the temperature?

W. Romanoff.—It should.

R. L. Binnney.—As to the Hoskins pyrometer, we have a file on them, and they have a proctecting tube and it causes a lag and then the protecting tube burns out and the molten metal gets in and destroys your thermal couple, and if you try to save it, it takes a fellow thirty minutes to reclaim the couple, and it is a great deal of trouble, putting those little insulators around the thermal couple in the protecting tube. We threw that out and used the bare metal couple in an effort to get away from the lag that was caused by the protecting sheet.

W. Romanoff.—In regard to using the tube and the thermal couple, we don't use any tube or insulator at all. We use the base metal and we have figured out the difference in temperature with the couple burning off—when it starts burning off. We know just how long we want to keep that couple in the metal. We know there is a difference in temperature dependent upon the resistance, and that is directly proportional to the length of your thermal couple, and by calibrating against a standard couple we are able to maintain a standard system. We seem to be able get accurate results by checking it weekly, or sometimes oftener if we think anything is wrong.

You mention giving a certain standard temperature for a certain analysis. With the great number of alloys used throughout the nonferrous industry that is practically impossible. We

have worked this out on our own analysis. We know what our temperature should be on those particular ones, and we have found that the lower the pouring temperature, the stronger will the metal be. As far as giving definite figures, that is impractical.

A member.—What is your pouring temperature on 88-10-2?

W. Romanoff.—88-10-2 will run about 2100, sometimes a little higher and sometimes a little lower, dependent upon the size of the casting.

Unknown.—If you get below that you are going to have leakage.

W. Romanoff.—That is where the gating would enter in. We pour one thin casting on which we must go above. It is a frog used for an electric railway, and has a very thin section, and a number of times we couldn't begin to pour at 2100.

A member.—At high lead I pour higher than 2100.

Mr. Romanoff.—Our highest lead alloy is about 9½ per cent, and we go below 2100.

A member.—We have 23 per cent lead, and we have to do it to stop leaks.

W. Romanoff.—You investigate your gating and see if you can't increase it, but don't increase it to a size where you will have difficulty cutting it off.

Mr. Wood.—I want to corroborate what Mr. Comstock said about the use of silicon for high conductivity. I would certainly class it among the better deoxidizers to use for high conductivity metal.

As to fluxes in the use of brass melting, why wouldn't it be well to think of the use of fluxes in blast furnace practices? What are they for? They are to liquify the gangue. If you have a blast furnace that isn't properly fluxed you have a mess, because you have a mixture of gangue material and metal material, and you can't separate it. The only essential difference I see between the brass furnace conditions and the blast furnace is that you have a large quantity of gangue you have to get rid of, as compared with a small quantity of metal.

The function of the flux, to my mind, is this: That you will form a chemical union between the impurities that may be

present and intermixed with either chips or gates and risers, by which you assist the little globules of metal to come together and clear themselves from this earthly material and give that material a chance to get out from the metal. In that sense I think a flux is useful in cutting down the melting time, even though it may not have any direct effect upon the quality of the metal in the resulting casting.

W. Romanoff.—His point is well taken, in regard to fluxes. I agree that if you are using an impure metal in a brass furnace, flux is necessary, but in using almost pure metal, as virgin metal, and our own domestic scrap and cleanings, and borings, there is no particular advantage in using a flux. As far as increasing the melting time goes, I rather disagree with you. It depends upon the type of furnace you are using. If you have your flux forming a cover it acts as an insulator and prevents your heat getting at the metal, and I don't think you will increase the time by using a flux. Where the impurities are high, it is essential. As far as the flux acting as an insulator, that has been brought home in a very decided manner, in the case of using an electric furnace. If we don't skim that every fifteen minutes our heat is delayed enormously, because the slag is acting as an insulator and prevents the heat getting at the metal.

Linear Contraction of a Series of Brasses and Bronzes*

By Robert J. Anderson, Pittsburgh, and
Everett G. Fahlman, Cleveland

This paper is issued as a contribution to the literature of nonferrous alloy foundry practice and is based on an investigation carried out by the Bureau of Mines in connection with its nonferrous metallurgical work. Experiments were carried out for the purpose of determining the linear contraction of a series of brass and bronze alloys on casting into sand molds with a view to obtaining data to be used for making pattern allowances in the production of nonferrous alloy castings. As is well known, a considerable variety of copper alloys, including ordinary bronzes, phosphor bronzes, zinc bronzes, lead bronzes, lead-zinc bronzes, red brass, yellow brass and others, are employed for castings in nonferrous foundry practice.

The usual figure employed for the pattern-maker's shrinkage allowance in the case of these copper alloys is taken as about 3/16 inch per foot, equivalent to 0.188 inch per foot, or 1.57 per cent. In reviewing the literature, it was found that there was a dearth of reported measurements of the linear contraction of nonferrous alloys although much work had been done, and many of the results reported, in the case of cast iron by Keep, West, and other early workers in the cast-iron foundry field. The roughly approximate figure given above for the linear contraction of copper-casting alloys is entirely too poor for good pattern work, and it is desirable to point out that it is good practice to determine the contraction of every alloy poured in the foundry, under a variety of definite conditions, and to make the pattern allowances accordingly. Of course, ordinarily, larger allowances than that indicated are employed in the case of manganese brass, monel metal, aluminum bronze, and other "high shrinkage" alloys. The investigation reported here was

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carried out along the general lines of another similar investigation on aluminum alloys conducted by one of the writers.[1]

So far as is known, no systematic study of the linear contraction of the commercial casting alloys of the brass and bronze type has been reported, although some papers have appeared dealing with the contraction of alloys embraced in a given binary system, for example, copper-zinc alloys, aluminum-zinc alloys, copper-tin alloys, and others. It is hoped, therefore, that the data given in the present paper will be found of interest to the nonferrous foundry industry. In the case of 21 alloys examined in the investigation reported here, the linear contraction on pouring bars into sand molds was found to vary roughly between 1.1 and 2.2 per cent. Of course, the linear contraction is a function of the chemical composition of the alloy, the type of mold used, the pouring temperature, size of section, method of gating, and other factors. Obviously, in pattern work, the proper value for contraction should be employed, and the pattern allowance to be made can be determined by making contraction measurements for the different alloys over a range of pouring temperature and size of section. The more theoretical aspects of the problems involved in the study of contraction have been discussed by one of the writers[2] elsewhere, and these need not be considered here. In the present paper, figures are given for the linear contraction of a series of 21 copper alloys of the brass and bronze type on pouring into sand molds under definite conditions.

Object and Scope of Experiments

The object of the investigation reported here was to determine the linear contraction of a series of brass and bronze alloys used generally in foundry work. The number of alloys

1—Anderson, R. J., Linear contraction and shrinkage of a series of light aluminum alloys, paper before the Am. Foundrymen's Assn., Cleveland meeting, May, 1923.

2—Anderson, R. J., Contraction and shrinkage of nonferrous as related to casting practice, Bureau of Mines Monthly Reports of Investigations Serial No. 2410, November, 1922.

Anderson, R. J., *loc. cit.*

was limited to 21, but these include the principal alloys employed today in nonferrous foundry practice. It was desirable to extend the investigation considerably so as to include a number of other alloys and to examine the effect of varying percentages of impurities upon the contraction of the ordinary alloys, but time was not available for so extending the investigation. Measurements were made of the linear contraction of the 21 selected alloys on pouring into sand molds at two different temperatures (a high pouring temperature and a low pouring temperature) and in two different size cross sections of bars (½-inch square and 1-inch square). The method of the investigation consisted in measuring the linear contraction of the alloys on casting into sand molds between the faces of cast-iron templates. The faces of the templates were 12.000 inches apart, and the details of the method of experiment are discussed in a later section of this paper.

General Information and Previous Work

Not many data are available in the literature relating to the linear contraction of brass and bronze alloys on pouring into molds, but a summary of the available data and a guide to the literature have been given in papers by one of the writers.[1] It may be pointed out that the bulk of the reported work, in the case of data for the contraction of nonferrous alloys, has been carried out by Turner and his students in connection with studies with the Turner extensometer. For the purpose of the present paper, the linear contraction of a metal or alloy may be taken as the diminution of length which takes place on cooling in a mold, and the terms linear contraction and pattern-maker's shrinkage are synonomous. Turner states that the shrinkage may be defined as the difference between the length of a casting and that of the pattern from which it was produced, i.e., it is the difference in volume between the fluid metal in the mold and the resultant casting at the ordinary temperature. In experimental measurements, the linear contraction may be most

1—Anderson, R. J., papers cited.

readily determined by measuring the diminution in length of a bar cast from a pattern of definite length. The linear contraction may be expressed in percentage diminution in length, in inch per foot, or in terms of the pattern-maker's shrinkage scale.

Full discussion of the technical aspects of the contraction problem need not be included here, since that has been given in other papers by one of the writers,[1] but it is of interest to include a short review of work by other investigators. As is well known, Keep has described an apparatus for measuring the contraction of cast iron, as has West, and the methods of these investigators have been applied in determining the contraction of the nonferrous alloys. Turner and Murray[2] have studied the cooling changes occurring in the copper-zinc series of alloys, using the Turner extensometer, and have reported many figures. Thus, for 70:30 brass, these investigators obtained the value 0.202 inch per foot for the contraction, in the case of ½-inch square bars poured in sand. For 60:40 brass, they obtained 0.178 inch per foot. In another paper, Haughton and Turner[3] discuss the contraction of alloys in the copper-tin system. Just recently, Johnson and Jones[4] have described a new form of apparatus for determining the contraction of alloys and have presented figures as to the contraction of the copper-zinc alloys.

Many data as to the contraction of copper casting alloys and the allowance to be made for the contraction when constructing patterns are given in hand books and in trade literature, and attention may be directed to the figures published just

1—Anderson, R. J., work cited.

2—Turner, T. and Murray, M. T., The copper-zinc alloys: a study of volume changes, *Jour. Inst. of Metals,* vol. 2, 1909, pp. 98-136.

3—Haughton, J. L. and Turner, T., Volume changes in the alloys of copper with tin, *Jour. Inst. of Metals,* vol. 6, 1911, pp. 192-212.

4—Johnson, F. and Jones, W. G., New forms of apparatus for determining the linear shrinkage and for bottom-pouring of cast metals and alloys, accompanied by data on the shrinkage and hardness of cast copper-zinc alloys, *Jour. Inst. of Metals,* vol. 28, 1922, pp. 299-326.

recently by the Lumen Bearing Co.[1] in its useful handbook on nonferrous alloys. Table I gives a summary of contraction data taken from this handbook. It will be noticed that the pattern allowance is not much different for the different alloys. It should again be emphasized that the contraction of any alloy is dependent upon a number of factors, of which the size of

Table I.

Pattern-Maker's Shrinkage Allowance of Non-Ferrous Alloys†

——Nominal composition of the alloys, elements, per cent——								Pattern-maker's shrinkage, inch per foot
Cu	Sn	Zn	Pb	P	Al	Fe	Mn	
10	...	86	...	...	4	...	...	1/8
80	20	...	...	*	...	...	...	1/8
84	16	...	...	*	...	...	...	1/8
90	10	...	...	*	...	...	...	3/16
88	10	2	...	...	...	...	...	3/16
86	9.5	2	2.5	...	...	...	...	3/16
86	12	1.5	0.5	...	...	...	...	3/16
80	10	...	10	*	...	...	...	3/16
79.5	12	...	7.5	1	...	...	...	3/16
85	5	5	5	....	...	...	...	3/16
78	8	...	14	*	...	...	...	3/16
93.5	6.5	...	...	*	...	...	...	3/16
99.8	...	...	...	...	...	...	...	7/32
57	0.75	40	...	...	0.5	1	0.25	7/32
83	6	2	9	...	...	...	...	3/16
90	...	...	...	...	10	...	...	7/32
89	...	...	...	...	10	1	...	7/32
90	6.5	2	1.5	...	...	...	...	3/16
88.5	11	...	0.25	0.25	...	...	...	3/16
87.25	11	...	1.5	0.25	...	...	...	3/16

†Based on Lumen Bearing Co.
*Deoxidized with phosphorus.

section and temperature of pouring are doubtless the more important. Turning now to a discussion of the work carried out in the investigation reported here, the method of experiment employed and the results obtained are taken up in the following paragraphs.

Alloys Examined For Contraction

The various alloys employed in the experimental measurements were made up in the foundry from primary commercial

1—Anon., Handbook for engineers and machine designers, Lumen Bearing Co., Buffalo, N. Y., 1922.

Table II.

Chemical composition of the brasses and bronzes employed in the experiments.[1]

Name of alloy	Number of alloy	Nominal composition	Chemical composition, elements, per cent. Cu	Sn	Zn	Pb	P	Ni	Mn	Fe	Al
Bronze	1	90:10 Cu-Sn	90.00	10.00	....	....	....	....	....	....	....
Bronze	2	85:15 Cu-Sn	84.22	15.78	....	....	....	....	....	....	....
Bronze	3	80:20 Cu-Sn	79.57	20.43	....	....	....	....	....	....	....
Phosphor bronze	4	89.8:10:0.2 Cu-Sn-P	89.69	10.04	....	....	0.25	....	....	....	....
Phosphor bronze	5	89.5:10:0.5 Cu-Sn-P	89.03	10.44	....	....	0.52	....	....	....	....
Zinc bronze	6	88:8:4 Cu-Sn-Zn	88.02	8.37	3.61	....	....	....	....	....	....
Zinc bronze	7	88:10:2 Cu-Sn-Zn	87.78	10.46	1.76	....	....	....	....	....	....
Zinc bronze	8	86:11:3 Cu-Sn-Zn	87.24	10.77	1.99	....	....	....	....	....	....
Zinc bronze	9	84:11:5 Cu-Sn-Zn	84.98	11.15	3.87	....	....	....	....	....	....
Lead-zinc-bronze	10	90:6:3:1 Cu-Sn-Zn-Pb	89.73	6.51	2.77	0.99	....	....	....	....	....
Lead-zinc-bronze	11	87:7:5:1 Cu-Sn-Zn-Pb	86.72	7.42	4.75	1.11	....	....	....	....	....
Lead-zinc-bronze	12	84:10:5:1 Cu-Sn-Zn-Pb	84.36	9.93	4.72	0.99	....	....	....	....	....
Lead-zinc-bronze	13	76:7:4:13 Cu-Sn-Zn-Pb	75.60	6.96	3.92	13.52	....	....	....	....	....
Lead-zinc-bronze	14	85:5:5:5 Cu-Sn-Zn-Pb	85.33	5.48	4.07	5.00	0.12	....	....	....	....
Lead bronze	15	80:10:10 Cu-Sn-Pb	78.55	10.81	....	10.48	0.13	....	....	....	....
Alpha brass	16	70:30 Cu-Zn	71.20	....	28.80	....	....	....	....	....	....
Tin brass	17	70:29:1 Cu-Zn-Sn	70.40	1.30	28.30	....	....	....	....	....	....
Muntz metal	18	60:40 Cu-Zn	61.14	....	38.86	....	....	....	....	....	....
Tin muntz metal	19	60:38:2 Cu-Zn-Sn	61.11	2.21	36.68	....	....	....	....	....	....
Nickel bronze	20	86:4:6:3:1 Cu-Ni-Sn-Zn-Pb	85.30	6.56	3.03	0.77	....	4.34	....	....	....
Manganese brass	21	56:40:1:1.5:1.5 Cu-Zn-Fe-Al-Mn	56.52	....	39.73	....	....	....	1.24	0.91	1.60

[1] Analyses by G. B. Dalrymple.

metals, and Table II gives the nominal and actual compositions of the alloys employed. The alloys were prepared by making fixed additions of various metals to copper, and some scrap alloys, i.e., gates and risers from previous melts, were employed in making up succeeding alloys in the series. In selecting the alloys for contraction measurements, it was the aim to include the more common brass and bronze alloys used in foundry practice, and some special alloys were also examined.

While it was desirable to extend greatly the number of alloys and to include testing the effect of pouring temperature and size of section on the contraction over a wide range, with the time available, it was necessary to limit the work to the alloys chosen and to pouring at high and low temperature and in two sizes of section.

Method of Experiment

As has been pointed out above, the linear contraction of any alloy on pouring into a mold is dependent upon a number of factors including the pouring temperature, size of test-bar section, and method of molding (size of gates, whether risers are used, etc.). It was not possible to examine the effects of a number of factors on the contraction of the alloys, but examination was made of the effect of varying the size of section and the pouring temperature. In the experimental measurements made, bars were cast in sand molds, in the various alloys, from wooden patterns ½-inch square by 12 inches long and 1-inch square by 12 inches long. The alloys were cast at two temperatures; viz., a high pouring temperature and a low pouring temperature. Thus, the effects of size of section and pouring temperature on the contraction of the alloys were examined.

The attempt was first made to pour the alloys at a definite number of degrees above the liquidus in all cases, but this was not possible because the melting points of certain of the alloys were not known with certainty. In other cases, the alloys became too sluggish at low temperatures to permit proper pouring, or else the castings became cold shut at a low pouring temperature which seemed sufficiently high for pouring. In the case

of certain of the zinc-containing alloys, it was not possible to pour at too high temperature because of loss of zinc due to volatilization. The differences between the high and low pouring temperatures for the different alloys varied considerably—from about 100 to 200 degrees Cent.

The alloys were melted in a pit coal-fired furnace using a graphite-clay crucible as the containing vessel. Melting and pouring temperatures were taken with a platinum platinum-rhodium thermocouple, and the pouring temperatures as given are accurate to ± 2 degrees Cent. In casting the bars, a heat was brought up slightly above the desired pouring temperature and then poured at the required temperature. All conditions of molding were held as constant as possible throughout the work.

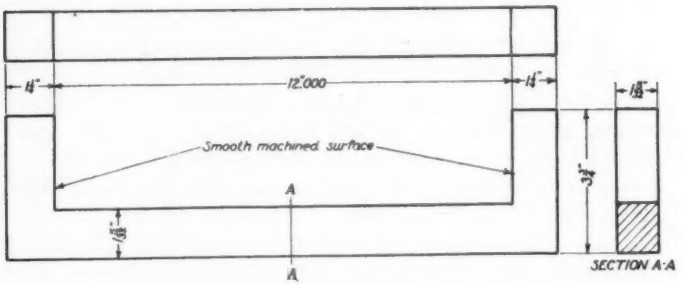

FIG. 1—FORM OF TEMPLATE USED IN POURING LINEAR-CONTRACTION BARS

Bars of the sizes mentioned were poured in sand molds between the faces of a cast-iron template, and the lengths were measured when the bars had cooled to the ordinary temperature. The template was 12,000 inches between the faces and of the form shown in the sketch of Fig. 1. The method of molding is shown in detail in the sketch of Fig. 2 while Fig. 3 shows the form of the cast bars with pouring gates attached, the 1-inch square bar being at the top and the ½-inch square bar at the bottom.

In molding, the bar patterns and the templates were molded together in the drag on the parting line with the cope, the 1-

inch bar and ½-inch bar being molded together in a flask as shown in Fig. 2. The patterns were then removed, leaving the templates in place, and the mold was then closed and poured, each bar being poured from a separate riser and from the same pot of alloy. In the case of the ½-inch square bars, a

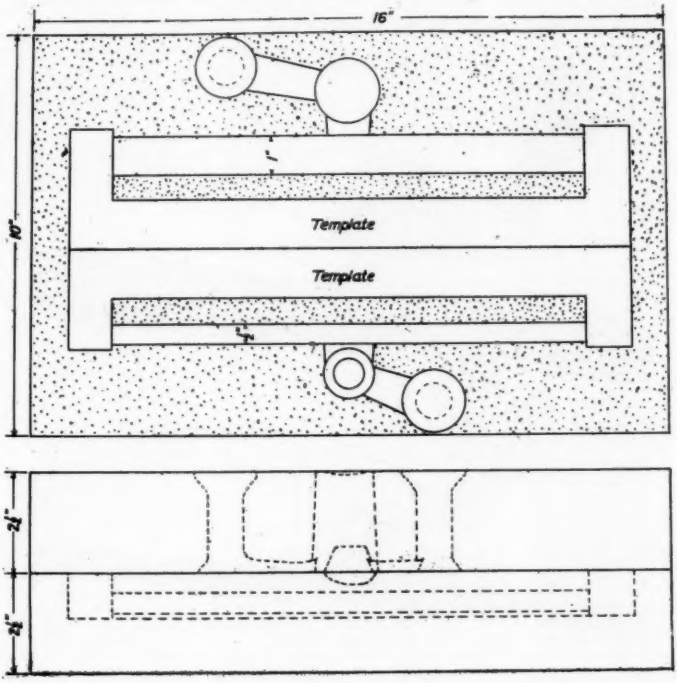

FIG. 2—METHOD OF MOLDING THE BARS

small shrink ball was molded to the runner as shown in the lower illustration of Fig. 3, while with the 1-inch square bar, a fairly heavy ball was used. No risers were used, but the molds were properly vented. The alloy was poured into the mold until the pouring gates were just full. Conditions as to the method of molding were maintained the same for the different alloys, i. e., the same size pouring gate and runner were

used, attempt was made to hold the moisture content of the sand approximately the same, and the hardness of ramming was practically the same for all the molds. In the case of the ½-inch square bars, the pouring gate was 2½ inches high and ⅞ inch in diameter, and the runner was ⅞ inch wide by ⅜ inch thick by 2 inches long. For the 1-inch square bars, the pouring

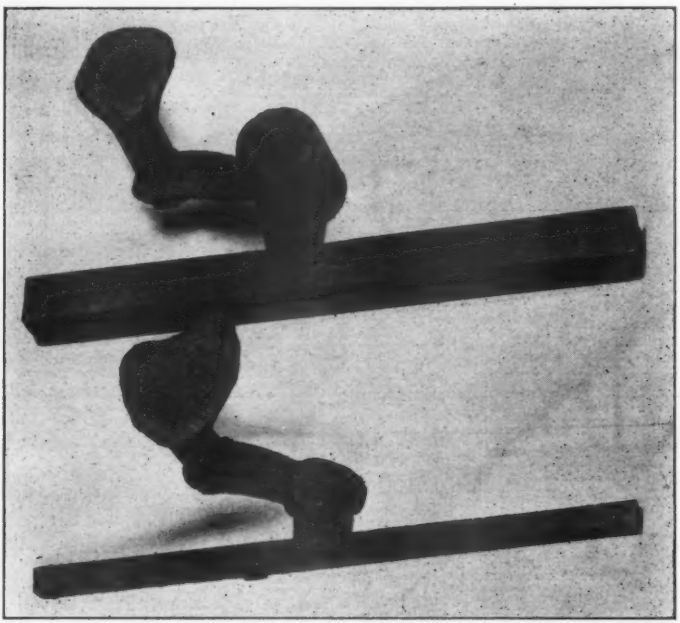

FIG. 3—PHOTOGRAPH OF THE CONTRACTION BARS WITH GATES ATTACHED

gate was 2½ inches high and ⅞ inch in diameter, and the runner was ⅞ inch wide by ⅜ inch thick by 2 inches long. The templates were made of grey cast iron machined to size and the same as those employed by one of the writers[1] in experiments on the linear contraction of aluminum alloys. There was found to be no measurable variation in the distance

1—Anderson, R. J., work cited.

between the faces of different templates or variation in the distances after repeated use. After pouring, the bars were shaken out of the molds after cooling for a short time, then cooled in air to room temperature, and measured as to length with a 12-inch vernier caliper.

Results of the Linear Contraction Measurements

Summaries of the measurements made on the linear contraction of the alloys are given in the accompanying Tables III to

Table III.

Linear Contraction of the Alloys, Poured at High Temperatures. ½-inch Square Bars.

Alloy number	Nominal composition	Pouring temperature		Linear contraction				Range of contraction, per cent, between high and low pouring temperatures
				Inch per foot	Per cent	Pattern-maker's scale		
		Deg. Cent.	Deg. Fahr.			Fraction of the length	Fraction inch per ft.	
21	56:40:1:1.5:1.5 Cu-Zn-Fe-Al-Mn	1,038	1,900	0.261	2.17	1/45	17/64	2.17—2.19
18	60:40 Cu-Zn	1,038	1,900	0.216	1.80	1/55	7/32	1.80—1.89
16	70:30 Cu-Zn	1,093	2,000	0.210	1.75	1/56	7/32	1.75—1.775
19	60:38:2 Cu-Zn-Sn	1,038	1,900	0.203	1.69	1/58	13/64	1.69—1.87
17	70:29:1 Cu-Zn-Sn	1,066	1,950	0.198	1.65	1/60	13/64	1.65—1.67
20	86:4:6:3:1 Cu-Ni-Sn-Zn-Pb	1,260	2,300	0.172	1.43	1/69	11/64	1.43—1.425
14	85:5:5:5 Cu-Sn-Zn-Pb	1,260	2,300	0.171	1.425	1/69	11/64	1.425—1.47
11	87:7:5:1 Cu-Sn-Zn-Pb	1,232	2,250	0.168	1.40	1/70	11/64	1.40— —
3	80:20 Cu-Sn	1,204	2,200	0.165	1.375	1/72	11/64	1.375—1.55
13	76:7:4:13 Cu-Sn-Zn-Pb	1,260	2,300	0.164	1.37	1/72	11/64	1.37—1.37
7	88:10:2 Cu-Sn-Zn	1,288	2,350	0.160	1.33	1/74	5/32	1.33—1.30
6	88:8:4 Cu-Sn-Zn	1,260	2,300	0.160	1.33	1/74	5/32	1.33— —
8	86:11:3 Cu-Sn-Zn	1,260	2,300	0.160	1.33	1/74	5/32	1.33—1.39
10	90:6.3:1 Cu-Sn-Zn-Pb	1,260	2,300	0.160	1.33	1/74	5/32	1.33—1.43
12	84:10:5:1 Cu-Sn-Zn-Pb	1,260	2,300	0.158	1.32	1/75	5/32	1.32—1.35
9	84:11:5 Cu-Sn-Zn	1,260	2,300	0.158	1.32	1/75	5/32	1.32—1.36
2	85:15 Cu-Sn	1,260	2,300	0.157	1.31	1/75	5/32	1.31—1.45
4	89.8:10:0.2 Cu-Sn-P	1,316	2,400	0.153	1.27	1/77	5/32	1.275—1.28
1	90:10 Cu-Sn	1,316	2,400	0.153	1.275	1/77	5/32	1.275—1.30
5	89.5:10:0.5 Cu Sn-P	1,316	2,400	0.151	1.26	1/78	5/32	1.26— —
15	80:10:10 Cu-Sn-Pb	1,260	2,300	0.150	1.25	1/79	5/32	1.25—1.31

VI inclusive. In the tables, the alloys are arranged in the order of their contraction, and the different tables give data for pouring at high and low temperatures and for the small and large bars. Table III gives the linear contraction of the series of alloys, poured at high temperatures, in the case of the ½-inch square bars, while Table IV gives the linear contraction of the alloys, poured at low temperature, for the same size section. The range of contraction for the alloys poured at high temperatures is from 1.25 per cent for the 80:10:10 copper-tin-lead alloy

to 2.17 per cent for the manganese brass. The range of contraction for the alloys cast at low temperatures is from 1.28 per cent for the 89.8:10:0.2 copper-tin-phosphorus alloy to 2.19 per cent for the manganese brass.

Table V gives the linear contraction of the alloys when poured at high temperatures, in the case of 1-inch square bars, while Table VI gives the contraction of the alloys when poured

Table IV.

Linear Contraction of the Alloys, Poured at Low Temperatures, ½-inch Square Bars.

Alloy number	Nominal composition	Pouring temperature		Linear contraction			
				Inch per foot	Per cent	Pattern-maker's scale	
		Deg. Cent.	Deg. Fahr.			Fraction of the length	Fraction inch per ft.
21	56:40:1:1.5:1.5 Cu-Zn-Fe-Al-Mn	927	1,700	0.263	2.19	1/4	17/64
18	60:40 Cu-Zn	927	1,700	0.227	1.89	1/52	15/64
19	60:38:2 Cu-Zn-Sn	927	1,700	0.225	1.875	1/52	15/64
16	70:30 Cu-Zn	982	1,800	0.212	1.77	1/55	7/32
17	70:29:1 Cu-Zn-Sn	954	1,750	0.200	1.67	1/59	13/64
3	80:20 Cu-Zn	982	1,800	0.186	1.55	1/64	3/16
11	87:7:5:1 Cu-Sn-Zn-Pb	1,010	1,850	..	..	..	..
14	85:5:5:5 Cu-Sn-Zn-Pb	1,093	2,000	0.176	1.47	1/67	11/64
6	88:8:4 Cu-Sn-Zn	1,093	2,000	..	..	..	..
2	85:15 Cu-Sn	1,038	1,900	0.174	1.45	1/68	11/64
10	90:6:3:1 Cu-Sn-Zn-Pb	1,038	1,900	0.172	1.43	1/69	11/64
20	86:4:6:3:1 Cu-Ni-Sn-Zn-Pb	1,149	2,100	0.171	1.425	1/69	11/64
8	86:11:3 Cu-Sn-Zn	1,093	2,000	0.167	1.39	1/71	11/64
13	76:7:4:13 Cu-Sn-Zn-Pb	1,093	2,000	0.165	1.375	1/72	11/64
9	84:11:5 Cu-Sn-Zn	1,093	2,000	0.163	1.36	1/73	11/64
12	84:10:5:1 Cu-Sn-Zn-Pb	1,093	2,000	0.162	1.35	1/73	5/32
15	80:10:10 Cu-Sn-Pb	1,093	2,000	0.157	1.31	1/75	5/32
5	89.5:10:0.5 Cu-Sn-P	1,093	2,000	..	..	..	..
7	88:10:2 Cu-Sn-Zn	1,121	2,050	0.156	1.30	1/76	5/32
1	90:10 Cu-Sn	1,093	2,000	0.156	1.30	1/76	5/32
4	89.8:10:0.2 Cu-Sn-P	1,149	2,100	0.154	1.28	1/77	5/32

at low temperatures for the same size section. The range of contraction for the alloys poured at high temperatures is from 1.11 per cent for the 89.5:10:0.5 copper-tin-phosphorus alloy to 2.08 per cent for the manganese brass.

Owing to the variable composition of the different alloys, the results do not lend themselves readily to discussion as to the effect of chemical composition of the copper-casting alloys

upon their contraction, and the data may properly be regarded as useful in indicating the contraction of different alloys of specific compositions. In Table IV, no data were obtained as to the contraction of three of the alloys at low pouring temperature because of mis-runs.

General Discussion of the Results

The results of the experimental measurements show that the linear contraction of a series of 21 copper alloys varies from

Table V.

Linear Contraction of the Alloys, Poured at High Temperatures. 1-inch Square Bars.

Alloy number	Nominal composition	Pouring temperature		Linear contraction				Range of contraction, per cent, between high and low pouring temperatures
				Inch per foot	Per cent	Pattern-maker's scale		
		Deg. Cent.	Deg. Fahr.			Fraction of the length	Fraction inch per ft.	
21	56:40:1:1.5:1.5 Cu-Zn-Fe-Al-Mn	1,038	1,900	0.250	2.08	1/47	1/4	2.08—2.18
16	70:30 Cu-Zn	1,093	2,000	0.211	1.76	1/56	7/32	1.76—1.73
17	70:29:1 Cu-Zn-Sn	1,066	1,950	0.202	1.68	1/59	13/64	1.68—1.67
18	60:40 Cu-Zn	1,038	1,900	0.196	1.63	1/60	13/64	1.63—1.90
19	60:38:2 Cu-Zn-Sn	1,038	1,900	0.188	1.57	1/63	3/16	1.57—1.97
20	86:4:6:3:1 Cu-Ni-Sn-Zn-Pb	1,260	2,300	0.172	1.43	1/69	11/64	1.43—1.42
10	90:6:3:1 Cu-Sn-Zn-Pb	1,260	2,300	0.171	1.425	1/69	11/64	1.425–1.42
14	85:5:5:5 Cu-Sn-Zn-Pb	1,260	2,300	0.169	1.41	1/70	11/64	1.41—1.42
3	80:20 Cu-Sn	1,204	2,200	0.168	1.40	1/70	11/64	1.40—1.53
11	87:7:5:1 Cu-Sn-Zn-Pb	1,232	2,250	0.165	1.375	1/72	11/64	1.375–1.30
9	84:11:5 Cu-Sn-Zn	1,260	2,300	0.164	1.37	1/72	11/64	1.37—1.27
8	86:11:3 Cu-Sn-Zn	1,260	2,300	0.161	1.34	1/74	5/32	1.34—1.335
13	76:7:4:13 Cu-Sn-Zn-Pb	1,260	2,300	0.161	1.34	1/74	5/32	1.34—1.37
12	84:10:5:1 Cu-Sn-Zn-Pb	1,260	2,300	0.159	1.325	1/74	5/32	1.325–1.32
7	88:10:2 Cu-Sn-Zn	1,288	2,350	0.156	1.30	1/76	5/32	1.30—1.27
6	88:8:4 Cu-Sn-Zn	1,260	2,300	0.153	1.275	1/77	5/32	1.275–1.27
4	89.8:10:0.2 Cu-Sn-P	1,316	2,400	0.153	1.275	1/77	5/32	1.275–1.23
15	80:10:10 Cu-Sn-Pb	1,260	2,300	0.152	1.27	1/78	5/32	1.27—1.275
2	85:15 Cu-Sn	1,260	2,300	0.152	1.27	1/78	5/32	1.27—1.375
1	90:10 Cu-Sn	1,316	2,400	0.148	1.23	1/80	5/32	1.23—1.275
5	89.5:10:0.5 Cu-Sn-P	1,316	2,400	0.133	1.11	1/89	9/64	1.11—1.14

about 1.1 to 2.2 per cent, depending upon a number of factors. These factors include the chemical composition of the alloys, the size of the section poured, the pouring temperature, and others. The effects of these factors may be discussed briefly here in the light of the experimental measurements made, but sufficient data are not in hand to warrant drawing definite conclusions. Not enough data are in hand to permit drawing conclusions as to the effect of various additive elements upon the contraction of given alloys. With reference to the effect of the pouring temperature upon the contraction of the alloys; theoretically, the higher the pouring temperature, the greater the con-

traction since less metal can be put into a mold cavity of a given size at a higher temperature than at a lower one. However, owing to gas occlusion and the evolution of gas on cooling and freezing, pouring at a high temperature may yield less contraction in an alloy than pouring at a lower temperature. In the case of the ½-inch square bars, it is found that of the 21 alloys, pouring at a high temperature resulted in greater con-

Table VI.

Linear Contraction of the Alloys, Poured at Low Temperatures. 1-inch Square Bars

Alloy number	Nominal composition	Pouring temperature		—Linear contraction—		Pattern-maker's scale	
		Deg. Cent.	Deg. Fahr.	Inch per foot	Per cent	Fraction of the length	Fraction inch per ft.
21	56:40:1:1.5:1.5 Cu-Zn-Fe-Al-Mn	927	1,700	0.262	2.18	1/45	17/64
19	60:38:2 Cu-Zn-Sn	927	1,700	0.236	1.97	1/50	15/64
18	60:40 Cu-Zn	927	1,700	0.228	1.90	1/52	15/64
16	70:30 Cu-Zn	982	1,800	0.208	1.73	1/57	7/32
17	70:29:1 Cu-Zn-Sn	954	1,750	0.200	1.67	1/59	13/64
3	80:20 Cu-Sn	982	1,800	0.184	1.53	1/64	3/16
10	90:6:3:1 Cu-Sn-Zn-Pb	1,038	1,900	0.170	1.42	1/69	11/64
14	85:5:5:5 Cu-Sn-Zn-Pb	1,093	2,000	0.170	1.42	1/69	11/64
20	86:4:6:3:1 Cu-Ni-Sn-Zn-Pb	1,149	2,100	0.170	1.42	1/69	11/64
2	85:15 Cu-Sn	1,038	1,900	0.165	1.375	1/72	11/64
13	76:7:4:13 Cu-Sn-Zn-Pb	1,093	2,000	0.164	1.37	1/72	11/64
8	86:11:3 Cu-Sn-Zn	1,093	2,000	0.160	1.33	1/74	5/32
12	84:10:5:1 Cu-Sn-Zn-Pb	1,093	2,000	0.158	1.32	1/75	5/32
11	87:7:5:1 Cu-Sn-Zn-Pb	1,010	1,850	0.156	1.30	1/76	5/32
1	90:10 Cu-Sn	1,093	2,000	0.153	1.275	1/77	5/32
7	88:10:2 Cu-Sn-Zn	1,121	2,050	0.153	1.275	1/77	5/32
9	84:11:5 Cu-Sn-Zn	1,093	2,000	0.153	1.275	1/77	5/32
6	88:8:4 Cu-Sn-Zn	1,093	2,000	0.152	1.27	1/78	5/32
15	80:10:10 Cu-Sn-Pb	1,093	2,000	0.152	1.27	1/78	5/32
4	89.8:10:0.2 Cu-Sn-P	1,149	2,100	0.148	1.23	1/80	5/32
5	89.5:10:0.5 Cu-Sn-P	1,093	2,000	0.137	1.14	1/87	9/64

traction than pouring at a low temperature in only two cases, viz., with the 86:4:6:3:1 copper-nickel-tin-zinc-lead alloy and the 88:10:2 copper-tin-zinc alloy. In the case of the 1-inch square bars, it is found that of the 21 alloys, pouring at a high temperature resulted in greater contraction in 11 cases. The fact that in the majority of instances less contraction was given in pouring at higher temperatures than at lower ones may be explained by the effect of gas occlusion.

In comparing the effect of the size of section upon the contraction, irrespective of the pouring temperature, it is found that in general greater contraction obtains when the alloys are poured in 1-inch bars than in ½-inch bars. This is to be expected on the basis of experience, since in casting practice it is known that thin sections contract less than thick sections. In casting practice, the contraction allowance to be made is dependent upon the mass of the casting, its design, and the relation between the thick and thin sections, so that for the same alloy, different pattern allowances must be made for thick and thin castings. In the experiments reported here, the least contraction of the various alloys was obtained in the case of ½-inch square bars poured at high temperatures, while the greatest was given by 1-inch square bars poured at low temperatures. In general, it may be said from this that the smaller the size of section and the higher the pouring temperature the less the contraction, and the greater the size of section and the lower the pouring temperature the greater the contraction.

In passing, it is of interest to refer to the piping of alloys in relation to their linear contraction and contraction in volume on freezing, and the effect of the pouring temperature upon piping (and consequently contraction) is shown well in Fig. 4. The photograph shows two 1-inch square bars of 85:5:5:5 copper-tin-zinc-lead alloy, with the shrink balls attached. The bar in the upper half of the figure was poured at 1,260 degrees Cent. and that in the lower half at 1,093 degrees Cent. There is con siderable piping in the shrink ball of the second bar, while the upper surface of the ball of the first bar is flat and not piped. This would indicate immediately that the contraction of the bar poured at 1,093 degrees Cent. would be greater than the one poured at 1,260 degrees Cent., although there was not any appreciable difference, the contraction of the former being 0.170 inch per foot and that of the latter 0.169 inch per foot. However, it was possible in many instances to find clear relations be-

tween the piping shown on the shrink ball and the linear contraction of the alloys.

In summing up the results of the work, it has been found, that:

(1) The linear contraction of a series of brass and bronze alloys, covering a fairly wide range of composition and including the usual commercial alloys, varies roughly from about 1.1 to 2.2 per cent, depending upon the chemical composition and other factors.

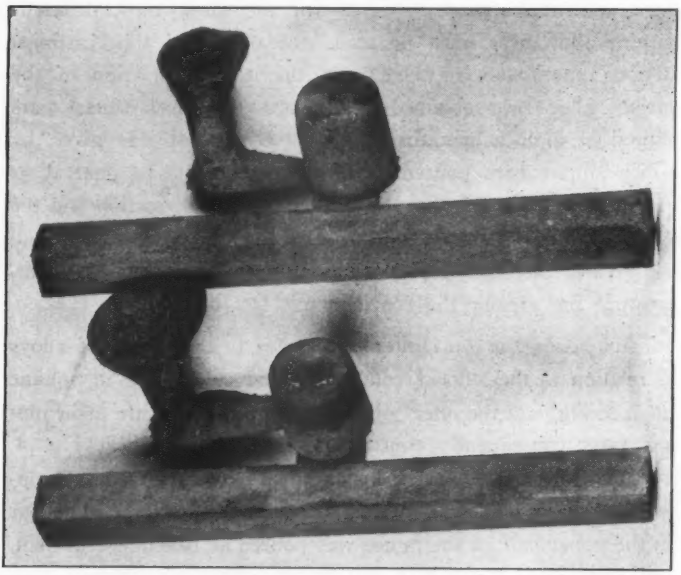

FIG. 4—PIPING IN SHRINK BALLS AS AFFECTED BY POURING TEMPERATURES, UPPER BAR POURED AT 1,260 DEGREES CENT., AND LOWER BAR AT 1,093 DEGREES CENT.

(2) In general, pouring at a high temperature yields less contraction than pouring at a low temperature because of the effect of gas occlusion.

(3) Other conditions being identical, the smaller the cross section, the less the contraction—within limits.

(4) The extent to which piping occurs on casting an alloy

is a factor in determining the suitability of an alloy for casting purposes since the amount of piping is an indication of the contraction in volume. The less the piping, the less the contraction.

Casting Bronze Tablets

By Jacob G. Kasjens, Peoria, Illinois

The casting of a bronze tablet is a very high grade piece of work and it is essential that careful attention be given to the flask, sand and every detail of the operation.

Flask

The cost of making a tablet is so great that one is justified in using a high grade flask. For a tablet about 20 inches wide by 30 inches long in size, a flask 35 inches wide by 40 inches long, inside measurements, should be used, the depth of the drag being six inches and the depth of the cope eight inches. Three-inch lumber should be used for such a flask and the corners should be well braced with angle iron. There should be three tie rods in the cope and a similar number in the drag. Bars should be fitted in the cope only. The guide pin should be well fitted and if a crane is available, there should be a trunnion on each end of the flask.

Sand

Any good sand that is suitable for other fine brass work can be used for making tablets. It should be prepared the day before it is used. First, put it through a No. 10 sieve, adding about one part of kordex core compound, or any other good core compound, to 40 parts of sand. Sieve again through the same mesh so as to thoroughly mix the compound with the sand, then dampen to the required moisture and sieve through a No. 4 sieve. The sand and compound by this time should be well mixed and the heap should be covered over night by well dampened gunny sacks. This will give a strong, mellow mixture which will not require brads to hold the particles of sand between the letters.

Ramming

When the match is prepared and the pattern in place, a very small amount of lycopodium should be shaken upon the pattern. Any excess lycopodium should be blown off the pattern or it will cause trouble when spraying the mold, as lycopodium

has no affinity for water. Now, put the drag in place, and to avoid "ramming away" from the letters or edge of the tablet, ram the facing sand by gravity, as follows:

If a crane and electric riddle are available, hoist the riddle 10 or 12 feet high. If no crane is at hand, a step ladder can be utilized. Sieve about an inch of facing sand upon the pattern, then use a coarser sieve and finally fill the drag from the same height. Peen around the ends and sides of the flask. Step off the mold and butt ram it. Before putting on the bottom board, vent freely with a wire of medium size to within a half inch of the pattern. In ramming the cope, set a small sprue at each end for pop gates and a large sprue on each side, in the center, for pouring. Use about three-fourths inch of facing sand, then fill in with other sand and ram it in the ordinary way. It is not necessary to ram the cope by gravity, there being nothing to "ram away" on the back of the tablet. Vent the cope in a similar manner to the drag.

Lifting the Pattern and Spraying the Mold

Secure the pattern so as to lift it with the cope, raising it very slowly to allow for breaking the vacuum. The gates to the casting should be about ⅝-inch wide by ⅜-inch deep and they should be about 1½-inch apart. It is not necessary to flour the mold. It should be sprayed, however, with molasses water. Use one part of molasses to 15 parts of water and heat until thoroughly mixed. Use the ordinary foundry spray can with 60 to 80 pounds of air pressure. The can should be far enough from the mold and held high enough, so that the molasses water will reach the mold in the form of a mist. About two quarts of the spray mixture should be used on the drag of a mold for a 20-inch by 30-inch tablet and about half this quantity for the cope.

Drying

It will not be found necessary to dry the molds in the oven, but this can be done by means of a gas torch. The drying process should not be allowed to proceed too rapidly, thus avoiding blistering the face of the mold and burning the pyramids of sand.

Clamping the Mold

Before closing the mold, plenty of paste should be used on the joints of the flask to avoid run outs. Clamp the flask carefully and then place an iron rail or I-beam across it, fitting wooden wedges between it and the bars in the cope, so that the sand in the center of the cope cannot rise during pouring.

Pouring

On a tablet of the size mentioned above, two crucibles should be used for pouring. Where tablets of a greater area are made, additional crucibles should be used so as to cover the required area with safety. Unless this precaution is taken, strained or mis-run castings will result.

Alloys

Any standard art bronze alloy will run well and make a good casting. In some cases, it may be necessary to use a special mixture in order to match the color of bronze work already in place.

Melting

Whether the melting is done in crucibles or open flame furnaces, care should be exercised to avoid overheating the metal. It should at all times be covered with charcoal.

Cleaning Castings

When a casting is taken from the mold, it should be examined by filing a number of letters several places on the face of the border in order to ascertain whether it is free from pinholes. If the casting is found to be sound, the gates can then be removed and the casting cleaned.

Finish

In finishing the casting, the border surface is filed straight, the letters are faced and then draw-filed to take out the waves.

Coloring or Ageing

In order to thoroughly clean the face of the tablet and give the acid dip an opportunity to act uniformly, the casting should be cleaned by the sand blast before starting the coloring process. It requires considerable skill and experience to bring out the beautiful color desired.

Final Finish

For the final finish, fine emery paper fitted to a block of wood is used and all polished surface rubbed one way to eliminate waves. When a tablet has to be placed inside of a building, it is lacquered. Tablets that go outside age better and more quickly if not lacquered.

Conclusion

The making of tablets in a jobbing foundry requires so much attention and care that it naturally influences the general character of the work done in such a foundry. For this reason, it is desirable work, because it will raise the standard of the work done by the foundry along other lines.

Linear Contraction and Shrinkage of a Series of Light Aluminum Alloys[1]

By Robert J. Anderson, Pittsburgh

A.—Introduction

a.—General

The rapid growth of the automotive industry in recent years has increased greatly the demand for light, strong, and readily machineable castings, and aluminum alloys, consequently, have found extensive use for motor-car construction. Moreover, owing to the greatly stimulated interest in the light alloys during the war, in connection with their employment for aeronautical purposes, these alloys have been put to many new and varied uses by the general engineering trades. Because of the high contraction and hot shortness of the usual light aluminum alloys, the founding of aluminum-alloy sand castings is beset with a number of difficulties not encountered in working with the ordinary brasses and bronzes or with cast iron and steel. A considerable percentage of the wasters now normally obtaining in aluminum-alloy foundry practice is due to the high contraction of the alloys (i. e., to failure to control the contraction) and to their hot shortness, and these factors markedly affect the occurrence of cracks and other defects in the resultant castings.

The question of casting losses and wasters in aluminum-alloy foundry practice has been investigated by the bureau of mines, and the results of study have shown that at least 20 per cent of the wasters are due to cracks [34.35] in the castings. In connection with an investigation of cracks in aluminum-alloy castings, the preliminary results of which have been reported [49] and which showed that the contraction of the

[1]Published by permission of the director, United States bureau of mines.
[2]Numbers refer to published works given in the bibliography at the end of the paper.

alloys is a cogent factor in determining cracking tendency in the production of both sand castings and die castings, it became desirable to make determinations of the linear contraction and patternmaker's shrinkage of a series of alloys. It had been found, other conditions being the same, that one alloy having relatively high contraction was more prone to crack on casting than another alloy having low contraction. Now, while the contraction of the alloys is only one of a number of factors which have a bearing on the occurrence of cracks in castings, still it is an important factor, and comparative figures for the contraction of the various light alloys will serve to determine the cracking tendency.

Turner ([41]) has discussed a number of factors which affect the casting properties of alloys in general, and among these factors, the question of contraction is given a prominent place. It may be added, in passing, that a systematic investigation of the casting properties of the light alloys, carried out according to the outline of influencing factors as suggested by Turner, would be of great value to the light alloy industry. It may be pointed out that, so far as is known, no systematic study has been made hitherto of the contraction of aluminum alloys on pouring into molds, and it is hoped that the data presented in this paper will be found of value by the industry.

While the bulk of the production of light aluminum-alloy castings, in the United States, is made in the 92:8 aluminum-copper alloy (nominal composition), a number of other alloys are employed commercially, and the tendency now is toward the increased use of special alloys for particular purposes. In pattern practice, the usual figure employed for the contraction of the light aluminum alloys is 0.156 inch per foot or 1.30 per cent, equivalent to 1/76 on the patternmaker's scale. This is a roughly approximate figure, altogether too poor for good pattern work, and the view which it is desired to put forward here is that it is good practice to determine the contraction of each alloy, employed in the foundry, under a variety of definite conditions, and to make the pattern allowances accordingly.

In the case of 40 alloys examined in the investigation reported here, the linear contraction on pouring bars into chill molds and sand molds was found to vary roughly between 0.95 and 1.80 per cent, or the contraction of some alloys was nearly twice as great as that of others. Of course, as will be shown in detail later, the linear contraction is a function of the chemical composition of the alloy, the type of mold used, the pouring temperature, size of section, method of gating, and other factors. Obviously, in pattern work for aluminum-alloy sand castings and in the construction of steel dies for die castings, the proper value for contraction should be employed, and the pattern allowances to be made can be determined by making contraction measurements over a wide range of pouring temperature and size of section.

The more theoretical aspects of the problems involved in the study of contraction are discussed briefly in the present paper, and figures are given for the linear contraction of a series of 40 alloys under different definite conditions. This paper is issued as a contribution to the literature on the metallurgy of the light aluminum alloys, being an abstract of a complete report which will be published later by the bureau of mines.

b.—General Aspects of the Linear-Contraction Problem

Turning now to a consideration of the more general aspects of the contraction problem as related to design, pattern making, and foundry practice, it is of importance to point out the need for, and value of, accurate linear-contraction figures for the alloys. The remarks about to be made here refer specifically to aluminum alloys, but they can be applied largely to metals and alloys in general.

In pattern making, as is well known, present ordinary practice usually entails making first a master pattern in wood for any desired casting, and then from this the standard metal pattern, to be employed in production, is cast. This refers, of course, to repetitive jobs where the number of castings to be made is large and where specifications as to dimensions are close. Now, a pattern maker, not of broad experience in aluminum-alloy work but required to employ an approximate figure

for the contraction of the alloys or to rely on data given in engineering handbooks, could not possibly make on one trial a wooden master pattern that would give cast metal patterns which would yield in turn castings of the required dimensions. Invariably, it is necessary, even in the case of skilled pattern makers of much experience with the alloys in question, to file, scrape, or build up the metal pattern at various positions so that castings of the required dimensions can be poured.

Thus, ordinarily, in the preparation of metal patterns for important repetitive work in founding, e. g., crankcases, it is necessary to proceed about as follows: First, a wooden pattern will be made and then a metal pattern cast therefrom. Then a few castings will be poured from the metal pattern to determine where the dimensions are incorrect and where the defects occur, and the required changes will be made on the wooden pattern. Then, another metal pattern will be poured from the corrected wooden pattern, and more castings poured, and so on. Corrections will continue to be made until a wooden master pattern is obtained that will give a metal pattern of the correct dimensions which in turn will yield castings of the size and tolerances required. In all cases, the construction of a master pattern is based on the principle of cut-and-try, and when an inaccurate value is employed for the contraction, the procedure described above may be lengthened almost interminably.

The procedure described is expensive and unscientific, and after being carried out often yields patterns which are almost certain to give rise to defective castings. Where a pattern shop, in charge of a competent pattern maker, is attached to an aluminum-alloy foundry, it is desirable that data should be available for the contraction of all alloys employed, and such data should include figures for the contraction of the alloys as affected by the important factors which influence the values. While, even with rule-of-thumb methods, an intimate knowledge of the behavior of various alloys on casting and experience with a variety of designs will permit practical pattern makers to construct good patterns, still these methods are technically incorrect. As has been indicated, the view which it

is desired to put forward here is that data for the contraction of the various alloys should be of especial value in pattern practice, and that information as to the effects of various factors, such as the pouring temperature and size of section, should accompany contraction determinations.

Of course, any casting should be designed with especial regard to foundry practice, i.e., as to the alloy to be used, the gating necessary, size of sections, pouring temperature required, and other factors. The proposed design, which should be the result of the combined knowledge of the foundryman, pattern maker, metallurgist, and designing engineer, should be submitted to the pattern maker with a statement of the definite conditions of the foundry practice to be followed. If, now, in addition, accurate figures were available as to the contraction of the alloys, together with information as to the effects of various factors, such as the size of sections, pouring temperature, and method of gating, upon the contraction, then it would be a much more simple technical problem to construct a pattern that would yield castings of the required dimensions and with a minimum number of wasters in production than it is where a general rough value is employed for the pattern allowance for all aluminum alloys.

B.—General Information and Prior Work

a.—General

Not many data are available in the literature, relating to the linear contraction of aluminum alloys on pouring into molds, and scant information has been presented as to the total contraction in volume of alloys on passing from the liquid state to the solid state. The linear contraction, or shrinkage improperly so-called, may be regarded as the difference in length between a cast bar and the pattern from which it was molded, or the length of the mold into which it was poured. This gives rise to the term "pattern-maker's shrinkage." From the foundry point of view in examining the causes for cracks and other defects in castings, and particularly from the point of view of design and pattern making, it is of importance to have an abundance of data relative to the so-called "solidifica-

tion shrinkage," the "liquid shrinkage," and the "solid shrinkage" of alloys. Before considering the prior work on the contraction of alloys, it is advisable to have clearly in mind the meanings of several terms, and it may be added that there is considerable confusion on the question.

b.—Definition of Terms

When a metal, or alloy, is cooled from the liquid state at any temperature to the solid state, say at room temperature, it undergoes a diminution in volume. This diminution in volume is the algebraic sum of three separate contractions in volume; viz., (1) the contraction in volume in the liquid state, on cooling from any temperature in the liquid state to the freezing point; (2) the contraction in volume on passing from the liquid state at the freezing point to the solid state at the melting point; and (3) the contraction in volume on passing from the solid state at the melting point to any lower temperature. These three contractions in volume have been termed respectively (1) the liquid shrinkage, (2) the solidification shrinkage, and (3) the solid shrinkage, and they will be so referred to in the present paper. Reliable data as to the contraction in volume of the various metals on passing from the liquid state to the solid state are scant, but on the basis that practically every well-defined property of the elements is a function of their symbol weights, it may be deduced that the contraction in volume of the metals is a periodic function of their atomic weights. In fact, this has been shown by Toepler ([5]) and others.

1. *Liquid Shrinkage.* The liquid shrinkage may be defined as the amount of contraction in volume of a metal or alloy on cooling from any temperature in the liquid state to the beginning of freezing. The greater the temperature interval through which the metal cools, i. e., the higher the initial temperature of the melt, the greater the liquid shrinkage. The liquid shrinkage is not, therefore, a definite numerical value, but it varies with the temperature interval of cooling. The liquid shrinkage of aluminum and certain of its alloys is a nearly linear function of the temperature from which cooled, since the density in the liquid state varies quite uniformly with

the temperature, as has been demonstrated by experimental measurements. Incidentally, the consideration of liquid shrinkage explains why a less weight of metal can be poured into a mold at a higher temperature than a lower one, and it also indicates the necessity of feeding gates and risers, in molding castings, for the purpose of supplying liquid metal to the contracting portions of the casting.

2. *Solidification Shrinkage.* The solidification shrinkage may be defined as the contraction in volume of a metal or alloy on passing from the liquid state at the freezing point to the solid state at the melting point. Where an alloy solidifies over a freezing range, the solidification shrinkage is the contraction in volume which occurs from the beginning to the end of freezing. So far as is known, bismuth and silicon are the only metals that expand on freezing, but some alloys expand, and a number of alloys show expansions on the Turner extensometer, on cooling from liquid to solid although the total volume change is a decrease.

3. *Solid Shrinkage.* The solid shrinkage is the contraction in volume which occurs on cooling a metal or alloy from the solid state at the melting point to any lower temperature, usually the ordinary temperature, and it may be determined over any solid-temperature range by experimental measurements or by calculation from the formula for expansivity. The thermal expansivity is the reciprocal of the solid contraction.

4. *Thermal Expansivity.* Reliable data for the thermal expansivity of the various aluminum alloys are not numerous. The coefficient of expansion of the commercial light alloys varies between 22 x 10^{-6} and 27 x 10^{-6}, as compared with 22.31 x 10^{-6} for substantially pure aluminum, where the 90:10 aluminum-copper alloy has the lower value for expansion, and the 95:5 aluminum-magnesium alloy has the higher value. The light alloys are subject to permanent growth on heating above 250 degrees Cent., but the growth is less than the thermal expansion.

The thermal expansion of aluminum over any temperature range in the solid state can be calculated from the formula

$$(22.31t + 0.01115t^2) \times 10^{-6}$$

5. *Linear Contraction.* The linear contraction of a metal or alloy may be defined as the diminution of length which takes place in a casting on pouring into a mold. The terms linear contraction and patternmaker's shrinkage are synonomous. Turner ([16]) states that "shrinkage" may be defined as the difference between the length of a casting and that of the pattern from which it was produced, i. e., it is the difference in length between the liquid metal in the mold and the resultant casting at the ordinary temperature. Linear contraction, or shrinkage, therefore, in this sense, does not take into account the various stages of contraction, arrests, or actual expansions which may occur in an alloy on freezing, but it is merely the final result or algebraic sum of the changes.

In the case of experimental measurements, the linear contraction of an alloy may be determined most readily by measuring the diminution in length of a bar cast from a pattern of definite known length. The linear contraction may be expressed in per cent diminution of length, in inch per foot, or in terms of the pattern-maker's shrinkage scale.

6. *Pattern-Maker's Shrinkage.* As has been pointed out, in pattern practice for light aluminum-alloy sand castings, the usual allowance for the contraction is 5/32 inch per foot (0.156 inch per foot, or 1.30 per cent), and if a casting is to be 1 foot long, then the pattern is made 1 foot and 5/32 inches in length. According to Keep ([17]), and his version of the matter is accepted by Turner and others, the general understanding is that the shrinkage of a casting is the difference in length (or any other linear dimension) between the casting and the pattern from which it was made, or rather between it and the mold in which it was poured. On the other hand, West ([10]) calls "shrinkage" the decrease in volume in the liquid state (that requires feeding in casting practice) and applies the term "contraction" to the decrease in volume which takes place after freezing. Too, according to McWilliam and Longmuir ([14]), "technically, 'shrinkage' refers to the gradual lessening in volume of the fluid metal as it approaches the solidification point at which 'shrinkage' ceases and 'contraction' commences, the latter being understood to refer to the lessening

in length or volume of the solid metal." Hailstone ([27]) states that "liquid contraction" is the local contraction which takes place in the heavy part of a casting when the outside skin of that casting has frozen. He states also that the "solid contraction" is the natural contraction which metals undergo when passing from the hot to the cold condition, solid contraction being known also as "shrinkage." It is apparent from the foregoing that the question of contraction from the foundry point of view needs considerable clarification in the use of terms.

The arbitrary terminology of West and others seems to be based on nothing rational, and the author prefers to employ the terminology of Keep and Turner which is at least technically correct, although it may be open to improvement.

Referring to the question of shrinkage rules, since most metals and alloys employed for castings contract more or less on cooling from the liquid state to the ordinary temperature, these rules are employed in constructing patterns so as to allow for the contraction. According to McCracken and Sampson ([40]), the shrinkage allowances usually employed for some alloys are as given in the subjoined table:

PATTERN SHRINKAGE ALLOWANCE FOR ALLOYS

Material	Shrinkage allowance inch per foot
Aluminum alloys	7/32
Cast iron	1/10-1/8
Brass	3/16
Steel	3/16

It is plain that in order to obtain a casting of the required size the pattern must be larger than the casting desired, and the allowance to be made is the shrinkage. The total shrinkage (contraction in volume) on cooling from any temperature in the liquid state to the solid state at the ordinary temperature is the algebraic sum of the liquid shrinkage plus the solidification shrinkage plus the solid shrinkage. Referring to the 92:8 aluminum-copper alloy, the liquid shrinkage of this alloy on cooling from 1,000 degrees Cent. (density, 2.434) to 700 degrees Cent. (density, 2.524) is about 3.5 per cent; the solidification shrinkage is about 7 per cent; while the solid shrinkage from the freezing point (540 degrees Cent., where freezing is com-

plete) to room temperature is 1.30 per cent. The total is thus 11.8 per cent.

Reverting to the question of shrinkage rules, such rules are graduated in the ordinary way, but the space between the graduation is longer, than the actual indicated space, by an amount equivalent to the linear contraction. The pattern-maker's shrinkage, i. e., the amount longer that a pattern should be in order to give a casting of the required length, can be calculated from the measured diminution in length of a bar on pouring, and an example will serve to illustrate the method of so doing.

Thus, if it is assumed that a 1.0-inch square bar of an alloy is poured into a mold space 12.000 inches long, and that the final measured length of the bar in the cold is 11.832 inches, then the linear contraction is 0.168 inch per foot, or 1.40 per cent. From this it is seen that in order to obtain a casting 11.832 inches long, it is necessary to have a pattern 12.000 inches long, and the length of the casting will be

$\frac{11.832}{12.000} \times 100 = 98.6$ per cent of the length of the pattern. Then, from the proportion

$$1.4 : 98.6 = 1 : X, \text{ or}$$
$$1.4 : 98.6 = 1 : 70$$

the shrinkage is 1 unit in 70 units, i. e., 1/70 of the length. Hence, a shrinkage rule to yield castings of the requisite size, from an alloy whose contraction is 0.168 inch per foot as above, should have its graduations spaced 1/70 of each unit longer than the graduations on a standard measuring rule.

Table 1 gives the linear contraction in per cent and the corresponding pattern-maker's shrinkage for the contraction range 0.090 to 0.225 inch per foot, which may be found useful for reference.

With the fundamental ideas given above as to contraction in mind, it is of interest now to turn to a brief consideration of the prior work done on the contraction of metals and alloys as reported in the literature

TABLE 1.

Conversion of measured diminution in length of a cast bar 12 inches long to per cent linear contraction and pattern-maker's shrinkage.

Linear contraction			Linear contraction			Linear contraction			Linear contraction		
Measured diminution in length, inch per foot	per cent	Pattern-maker's shrinkage	Measured diminution in length, inch per foot	per cent	Pattern-maker's shrinkage	Measured diminution in length, inch per foot	per cent	Pattern-maker's shrinkage	Measured diminution in length, inch per foot	per cent	Pattern-maker's shrinkage
0.090	0.75	1/132	0.124	1.03	1/96	0.158	1.32	1/75	0.192	1.60	1/62
0.091	0.76	1/131	0.125	1.04	1/95	0.159	1.325	1/74	0.193	1.61	1/61
0.092	0.77	1/129	0.126	1.05	1/94	0.160	1.33	1/74	0.194	1.62	1/61
0.093	0.775	1/128	0.127	1.06	1/93	0.161	1.34	1/74	0.195	1.625	1/61
0.094	0.78	1/127	0.128	1.07	1/92	0.162	1.35	1/73	0.196	1.63	1/60
0.095	0.79	1/125	0.129	1.075	1/92	0.163	1.36	1/73	0.197	1.64	1/60
0.096	0.80	1/124	0.130	1.08	1/92	0.164	1.37	1/72	0.198	1.65	1/60
0.097	0.81	1/122	0.131	1.09	1/91	0.165	1.375	1/72	0.199	1.66	1/59
0.098	0.82	1/121	0.132	1.10	1/90	0.166	1.38	1/71	0.200	1.67	1/59
0.099	0.825	1/120	0.133	1.11	1/89	0.167	1.39	1/71	0.201	1.675	1/59
0.100	0.83	1/119	0.134	1.12	1/88	0.168	1.40	1/70	0.202	1.68	1/59
0.101	0.84	1/118	0.135	1.125	1/87	0.169	1.41	1/70	0.203	1.69	1/58
0.102	0.85	1/117	0.136	1.13	1/87	1.170	1.42	1/69	0.204	1.70	1/58
0.103	0.86	1/115	0.137	1.14	1/87	0.171	1.425	1/69	0.205	1.71	1/57
0.104	0.87	1/114	0.138	1.15	1/86	0.172	1.43	1/69	0.206	1.72	1/57
0.105	0.875	1/113	0.139	1.16	1/85	0.173	1.44	1/68	0.207	1.725	1/57
0.106	0.88	1/113	0.140	1.17	1/84	0.174	1.45	1/68	0.208	1.73	1/57
0.107	0.89	1/111	0.141	1.175	1/84	0.175	1.46	1/67	0.209	1.74	1/56
0.108	0.90	1/110	0.142	1.18	1/84	0.176	1.47	1/67	0.210	1.75	1/56
0.109	0.91	1/109	0.143	1.19	1/83	0.177	1.475	1/67	0.211	1.76	1/56
0.110	0.92	1/108	0.144	1.20	1/82	0.178	1.48	1/67	0.212	1.77	1/55
0.111	0.925	1/107	0.145	1.21	1/82	0.179	1.49	1/66	0.213	1.775	1/55
0.112	0.93	1/107	0.146	1.22	1/81	0.180	1.50	1/66	0.214	1.78	1/55
0.113	0.94	1/105	0.147	1.225	1/81	0.181	1.51	1/65	0.215	1.79	1/55
0.114	0.95	1/104	0.148	1.23	1/80	0.182	1.52	1/65	0.216	1.80	1/55
0.115	0.96	1/103	0.149	1.24	1/80	0.183	1.525	1/65	0.217	1.81	1/54
0.116	0.97	1/102	0.150	1.25	1/79	0.184	1.53	1/64	0.218	1.82	1/54
0.117	0.975	1/102	0.151	1.26	1/78	0.185	1.54	1/64	0.219	1.825	1/54
0.118	0.98	1/101	0.152	1.27	1/78	0.186	1.55	1/64	0.220	1.83	1/54
0.119	0.99	1/100	0.153	1.275	1/77	0.187	1.56	1/63	0.221	1.84	1/53
0.120	1.00	1/100	0.154	1.28	1/77	0.188	1.57	1/63	0.222	1.85	1/53
0.121	1.01	1/98	0.155	1.29	1/77	0.189	1.575	1/62	0.223	1.86	1/53
0.122	1.02	1/97	0.156	1.30	1/76	0.190	1.58	1/62	0.224	1.87	1/52
0.123	1.025	1/97	0.157	1.31	1/75	0.191	1.59	1/62	0.225	1.875	1/52

c. Prior Work On Contraction.

Much work has been done and many of the results reported on the linear contraction of cast iron by Keep, West, and other early workers in the cast-iron foundry field, but only relatively little work has been reported in the case of the commercial non-ferrous alloys. The volume changes occurring in metals and alloys on passing from the liquid state to the solid state have been studied by a number of investigators, notably by Mallet, Roberts-Austen, Toepler, Vincentini and Omodei, and by Wrightson, and more recently by Turner and his students. The notes below are based on published material, taken up in chronological order.

One of the earliest investigations on the volume changes of metals was that carried out by Mallet (1), in which conical wrought iron vessels of known volume were filled with cast iron at its freezing point, and its relative density, when in this condition, was determined. Roberts-Austen (2) employed Mallet's method for the determination of the density of silver at the freezing point, and subsequently Roberts-Austen and Wrightson (3) made studies of the changes in volume of various metals on passing from the liquid state to the solid state, using the oncosimeter. These latter investigators gave the following values for the change in density on freezing for a number of metals; bismuth, —2.30 per cent; cast iron, +1.02 per cent; tin, +6.76 per cent; copper, +7.10 per cent; lead, +9.93 per cent; zinc, +11.10 per cent; and silver, +11.20 per cent. Vincentini and Omodei (4) have determined the density of a number of metals in the liquid state and the change in volume on melting, using the dilatometric method, results being given for tin, cadmium, lead, and bismuth.

The dilatometric method for determining the density of liquid metals was improved upon and employed by Toepler, who examined a number of metals. Toepler (5), in an early paper, determined the solidification shrinkage of aluminum to be 5.1 per cent, and he also found that the change in volume on solidification of the metals is a periodic function of their atomic weights. Richards (6) gave the density of liquid

aluminum as 2.54 as compared with 2.66 for the metal at the ordinary temperature.

Keep ([7, 17]) has described an apparatus for measuring the shrinkage of cast iron and also for examining the behavior of a test bar while cooling from the liquid state to room temperature, and his apparatus is applicable to the nonferrous alloys. West ([8, 9, 10]), too, has described an autographic apparatus for obtaining expansion and contraction records of solidifying cast iron, and this may be applied also to other metals and alloys.

As has been mentioned, Turner and his students have studied the length changes occurring in various metals and alloys when poured into bars in sand molds, using a modification of Keep's apparatus and called the Turner extensometer. Turner has referred to the changes observed as "volume changes," but this has been denounced by Rosenhain, Desch, and others, and it is evident that the changes recorded by Turner's extensometer are simply length changes. In one of his earlier papers, Turner ([18]) described the apparatus employed and the types of curves obtained.

Carpenter and Edwards ([15]) have made measurements of the linear contraction of certain copper-aluminum alloys containing up to 12.4 per cent copper. The method employed consisted in making a sand mold 13 inches long by ½ inch square. Two very thin needles were embedded in the mold exactly 12 inches apart, with the aid of a gage. The sand around the needles was embedded very loosely, so that it would offer as little resistance as possible to the movement of the needles during the contraction of the casting. When the alloy had cooled to the ordinary temperature, the distance between the needles was measured by a rule divided into 100ths of an inch. The results showed that the addition of aluminum up to 6.73 per cent had no effect on the contraction of copper, the linear contraction of copper being about 2 per cent; at 8 per cent aluminum, there is a marked rise in the contraction to 2.33 per cent, followed by a drop to 1.83 per cent with 10 and 12 per cent aluminum.

McWilliam and Longmuir ([14]) have discussed the question of contraction in their book on foundry practice, indicating that, among other variables, some factors which affect the amount of contraction in a casting are the contour of the pattern, the pouring temperature, the presence of blowholes, and the mass of the casting. These authors give the data in Table 2 for the contraction and shrinkage allowance for some metals and alloys.

TABLE 2.

Contraction and shrinkage allowance for some metals and alloys.*

Material	Linear contraction inch per foot	Usual contraction allowance in pattern making, inch per foot
Yellow brass	1/8 to 3/16	1/8 (in 10 inches)
Gun metal	1/8 to 3/16	3/16
Copper	7/32	1/4
Zinc	1/8 to 5/32	1/8
Aluminum	5/32 to 3/8	5/16
Grey cast iron	1/10 to 1/8	1/8
White cast iron	1/4	1/8
Steel	3/16	3/16

* Based on McWilliam and Longmuir.

Other authors of foundry text books have dealt with the contraction problem and given values for the pattern allowances to be made for different alloys, but these need not be cited here.

Turner and Murray ([16]) have studied the cooling changes occuring in copper-zinc alloys, using the Turner extensometer, and have reported many figures. Wüst ([18]) has described an apparatus used to detect minute changes in length that take place on cooling a cast bar, and he has reported a large number of results for the shrinkage of metals and alloys. Table 3 gives some of his figures for substantially pure metals. Ewen and Turner ([19]) have examined the changes occurring in the antimony-lead and aluminum-zinc alloys on cooling, Coe ([23]) has studied the effect of maganese on the expansion changes and total contraction of cast iron, and Hogue and Turner ([22]) have investigated the effect of silicon on the contraction of cast iron. Jones ([24]) states that the contraction of the 67:33 aluminum-

TABLE 3.

Contraction of some substantially pure metals.*

Metal	Pouring temperature, degrees Cent.	Contraction during freezing, per cent	Total contraction per cent
Lead	500	0.065	0.82
Lead	600	0.085	0.83
Zinc	650	0.08	1.40
Zinc	700	0.08	1.40
Zinc	750	0.08	1.40
Tin	550	0.1 to 0.15	0.44
Tin	500	0.1 to 0.15	0.55
Aluminum	800	.....	1.78
Aluminum	850	.....	1.78
Copper	1,250	expansion	1.42
Bismuth	500	.....	0.29
Antimony	710	.....	0.29
Antimony	750	.....	0.63
Antimony	800	.....	0.29
Antimony	1,050	.....	0.66

*Based on Wüst.

zinc alloy is 9/64 inch per foot as compared with 11/64 inch for the 92:8 aluminum-copper alloy.

Study of the changes on solidification of the copper-tin alloys has been made by Haughton and Turner ([25]), and Chamberlain ([26]) has examined the aluminum-copper series. That test bars of alloys increase in external dimensions during the course of freezing has been demonstrated thoroughly by the work of Turner and his collaborators, and this is of importance in practical founding since it affects the pattern allowance to be made. Desch ([28]) has discussed the subject of volume changes on freezing, and his paper is of especial interest in considering the more theoretical aspects of the freezing of metals and alloys. He gives a summary of the determinations made of increase in volume on passing from the solid to the liquid state in the case of a number of substantially pure metals, as made by a number of investigators, and the data are given in Table 4. It is pointed out by Desch that the Tammann relation for the change in volume on melting holds as referred to substances enclosed in capillary tubes sealed at one end and

TABLE 4.

Summarized results of determinations of volume changes in metals on passing from the solid to the liquid state.*

Metal	Increase in volume on melting, per cent.		
Sodium	2.5 (T)	2.5 (H)	....
Potassium	2.5 (T)	2.6 (H)	....
Tin	2.8 (T)	2.8 (Vand O)	....
Cadmium	5.2 (T)	4.72 (Vand O)	....
Lead	3.7 (T)	3.39 (Vand O)	....
Thallium	3.1 (T)	.....	....
Zinc	0.9 (T)	.....	....
Aluminum	4.8 (T)	.....	....
Tellurium	7.3 (T)	.....	....
Antimony	1.4 (T)	.....	....
Bismuth	—3.27 (T)	—3.31 (Vand O)	—3.0 (L)

* Based on Desch.

Note: Initials refer to authorities reporting the figures; viz.: (T) Toepler; (H) Hagen; (L) Lüdeking; and (Vand O) Vincentini and Omodei.

immersed in a bath where the temperature is only slightly above the freezing point. This relation is

$$\text{Delta v} = T_0 \left(\frac{dv'}{dT} - \frac{dv''}{dT}\right)$$

where delta v is the change of volume on melting in cubic centimeters per gram; T_0 is the absolute temperature of fusion, and dv′ and dv″ are the changes in volume, in cubic centimeters per gram, of the liquid and solid respectively per degrees Cent. Few alloys have been examined by the Tammann method.

Pascal and Jouniaux ([29]), employing the sinker method for determining the density of liquid aluminum, give the following results; density at the melting point, 2.41; at 800 degrees Cent., 2.36; and at 1,000 degrees Cent., 2.29.

In the *Metal Industry Handbook* ([38]), there are given the values shown in Table 5 for the contraction of various alloys; the values are approximate, and the compositions of the alloys are not given. The British Aluminium Co., Ltd. ([39]), in a trade booklet, gives the figures shown in Table 6 for the contraction of some aluminum alloys. Details of how the measurements were made are lacking.

Recently, experiments of value have been carried out by Edwards and his collaborators on the density of aluminum and some aluminum-copper alloys in the liquid state and on the con-

TABLE 5.

Contraction of some nonferrous metals and alloys.*

Material	Contraction, inch per foot
Thin brass	1/8**
Thick brass	1/8†
Gun metal rods	1/8**
Zinc	5/16
Copper	3/16
Bismuth	5/32
Tin	1/4
Lead	1/4
Aluminum	17/64
Delta metal	3/16
Manganese bronze	1/4

* From The Metal Industry Handbook, 1920.
** per 9 inches.
† per 10 inches.

traction in volume on freezing. Study has been made by Edwards and Moorman ([36]) of the density of aluminum from 20 to 1,000 degrees Cent., employing a densimeter for deter-

TABLE 6.

Contraction of some light aluminum alloys.*

Nominal composition	Contraction, per cent	Patternmaker's scale
96:4 Al-Cu	1.25	1/80
92:8 Al-Cu	1.20	1/84
88:12 Al-Cu	1.20	1/84
84:3:13 Al-Cu-Zn	1.24	1/81
82:3:15 Al-Cu-Zn	1.24	1/81
77:3:20 Al-Cu-Zn	1.12	1/89
91:8:1 Al-Cu-Mn	1.31	1/77
85:14:1 Al-Cu-Mn	1.21	1/83
100 Al	1.60	1/63

* Based on data of The British Aluminium Co., Ltd.

minations in the liquid state. According to these investigators, the solidification shrinkage of aluminum on passing from the liquid state (density, 2.382) at 658.7 degrees Cent. to solid metal (density, 2.55) at the same temperature is 6.60 per cent. This refers to 99.75 per cent aluminum (difference method of analysis). The liquid shrinkage of substantially pure aluminum on cooling from 1,000 degrees Cent. (density, 2.262) to 700

degrees Cent. (density, 2.371) is about 4.6 per cent, and the density of liquid aluminum may be expressed by the equation

$$D_t = 2.382 - 0.000272(t - 658 \text{ degrees Cent.})$$

where D_t is the density at any temperature t degrees Cent. in the liquid state. Knowing the density at any two temperatures, the liquid shrinkage on cooling from the higher to the lower temperature can be calculated. The solid shrinkage of aluminum, i. e., the reciprocal of the thermal expansivity, can be calculated over any temperature range from the formula

$$(22.31t + 0.01115t^2) \times 10^{-6}$$

As has been stated previously, the total shrinkage (contraction in volume) on cooling from the liquid state to the solid state is the algebraic sum of the liquid shrinkage plus the solidification shrinkage plus the solid shrinkage, and the figures in Table 7 will give an idea of the total contraction on casting

TABLE 7.

Total shrinkage of aluminum on passing from the liquid to the solid state. *

Temperature of pouring		Total of solidification and liquid shrinkage from t° C. (liquid) to solid at 658° C., expressed in per cent of the original volume.	Remarks
Deg. Cent.	Deg. Fahr.		
658	1,216	6.6	Calculated.
700	1,292	7.2	Calculated.
800	1,472	8.2	Calculated.
...	....	7.7	Measured on an ingot cast at 1,550° F.

* Based on Edwards and Moorman.

Note: The calculated values were obtained from the density of aluminum at the different temperatures in the liquid state and in the solid state.

aluminum from different temperatures as calculated from density determinations.

Edwards ([37]) has determined the contraction in volume of some aluminum-copper alloys from the beginning to the end of freezing; for the 92:8 aluminum-copper alloy, over the freezing-temperature interval 636 to 540 degrees Cent., the value is about 7 per cent. The liquid shrinkage of this alloy on cooling from 1,000 to 700 degrees Cent. is about 3.5 per cent, while the solid shrinkage from the freezing point (540 degrees Cent., where freezing is complete) to room temperature is 1.30 per

cent. It is thus seen that of the three separate contractions in volume that owing to actual freezing change from liquid to solid is the largest. Edwards and Gammon ([38]) have studied the piping effect in aluminum ingots and in some aluminum-copper alloy ingots in relation to the solidification shrinkage, and it is stated that the solidification shrinkage is responsible for the piping of a metal when it is cast, and that the extent to which piping occurs is a factor in determining the suitability of an alloy for casting purposes.

Rosenhain ([42]) and his co-workers state that their results on determinations of the linear contraction of various light aluminum alloys "indicate very clearly that differences in total contraction between the various alloys are insufficient to account for the difference in their behavior described by those using them in the foundry. Such difficulties as have at times arisen in connection with the casting of certain of the alloys, therefore, must be ascribed to other causes." To the author, this view of the question appears to be erroneous. Table 8 gives the results of determinations made by Rosenhain *et al.* on the linear

TABLE 8.

Linear contraction of some aluminum alloys in sand molds.*

Nominal composition, elements per cent					Contraction,	Patternmaker's
Al	Cu	Zn	Sn	Mn	per cent	scale
85	....	15	....	....	1.42	1/69
88	2	10	....	....	1.40	1/70
83.75	2.75	13.5	....	....	1.27	1/78
82	3	15	....	....	1.25	1/79
91	8	....	....	1	1.31	1/75
85	14	....	....	1	1.21	1/82
91	7	1	1	....	1.19	1/83
90	10	....	....	....	1.25	1/79
88	12	....	....	....	1.25	1/79
88.75	10	....	1.25	....	1.22	1/81
86.5	12	....	1.5	....	1.25	1/79

* Based on Rosenhain, Archbutt, and Hanson.

contraction of a series of alloys cast in sand molds between the faces of a steel template. The figures given refer to bars 10 inches long by 1.0 inch by 0.5 inch, cast in dried molds.

Stahl ([43]) has examined piping and blowhole formation on casting copper ingots, and some of his conclusions are of

interest as bearing upon the contraction problem in general. According to Waehlert ([44]), tin has a greater effect than either zinc or copper in reducing the piping of aluminum, and tin also reduces the piping of aluminum-copper alloys. In an anonymous article ([46]), data have been given for the contraction of some light aluminum alloys, as is shown in Table 9. Dix and Lyon ([48]) have determined the linear contraction of a series

TABLE 9.

Contraction of some aluminum alloys.

Nominal composition	Contraction, per cent	Patternmaker's scale
99 per cent Al	1.60	1/63
91:8:1 Al-Cu-Mn	1.31	1/76
88:12 Al-Cu	1.25	1/80
85:14:1 Al-Cu-Mn	1.21	1/83
93:7 Al-Si	1.11	1/90

of light aluminum-copper-silicon alloys containing up to 6 per cent copper and up to 9 per cent silicon; actual figures are not given in the paper cited, but data taken from the plotted points on their graphs are given in Table 10.

In a recent paper by Johnson and Jones ([50]), description is given of an apparatus devised for measuring the con-

TABLE 10.

Contraction of a series of aluminum-copper-silicon alloys.*

Nominal composition, elements per cent			Linear contraction, inch per foot
Al	Cu	Si	
97	0	3	0.164
94	0	6	0.161
91	0	9	0.163
95	2	3	0.171
93	4	3	0.165
91	6	3	0.168
92	2	6	0.158
90	4	6	0.157
88	6	6	0.157
89	2	9	0.160
87	4	9	0.152
85	6	9	0.150

* Based on Dix and Lyon.

Note: The figures are for 1-inch square bars cast in green sand between graphite blocks.

traction of alloys in chill molds, in which the motion of a contracting test bar is conveyed through two steel arms, gripped

rigidly by the cast bar, to a micrometer, the head of which is attached to one arm and the anvil to the other. The arms are supported on grooved wheels moving freely on horizontal spindles, and are set exactly 12 inches apart in the mold. The micrometer is so arranged that a diminution in length of the bar causes the micrometer head to recede from the anvil, the total recession representing the total linear contraction of the 12-inch length of bar lying between the steel arms. The linear contraction per foot is obtained by taking the difference between the micrometer reading when head and anvil are in contact before pouring and that after screwing up the head again to make contact with the anvil, when the recession caused by the contraction is complete. Data are given by these authors for the contraction of copper-zinc alloys in the range of composition 0 to 100 per cent copper, under their conditions of experiment. The contraction was found to lie in the range 0.175 to 0.311 inch per foot, depending upon the composition, 60:40 brass having the contraction 0.281 inch per foot. The results of Johnson and Jones on chill-cast ¾-inch square bars are all higher than those of Turner and Murray for ½-inch square sand-cast bars. The method for determining contraction as described by the former investigators is a useful one.

Figures for the linear contraction and pattern allowance for aluminum alloys appear in many foundry text books, in engineering hand books, and in trade publications, but usually a general figure is given, presumably applicable to all aluminum alloys. In the case of most reported figures, no information is supplied as to the size of section of bar poured, the temperature of pouring, or chemical composition of the alloy, and such values are entirely meaningless. In the general discussion of the results of the experimental work performed in the investigation reported here, the effects of various factors on the contraction of alloys on casting are dealt with, and in passing, it is of importance to point out that linear-contraction values, when reported, should be accompanied by detailed information as to the conditions surrounding the measurements.

C.—Materials Employed and Method of Experiment

a.—General

Two sets of experimental measurements of a series of light aluminum alloys were made in the investigation; viz., (1) a set of measurements on alloys cast into bar form in graphite molds, and (2) a set of measurements on the same alloys cast in sand molds between the faces of a cast-iron template. The bars poured in graphite molds were made in the nonferrous metallurgical laboratory of the bureau of mines, and the sand-cast bars were poured in the foundry at the Carnegie Institute of Technology. In all, substantially pure aluminum and 40 light alloys were examined as to linear contraction in chill molds and sand molds.

b.—Chemical Composition of the Materials Employed

Except where otherwise stated, primary commercial metals were employed in making up the various alloys, and the chemical compositions of the individual metals and intermediate alloys used are given in Table 11. The aluminum used in the experiments was 99+ per cent metal, and most of the various alloys

TABLE 11.

Chemical composition of metals and alloys employed in the preparation of the light alloys. *a*

Metal or alloy	Elements, per cent									
	Al*b*	Cu	Fe	Si	Mg	Mn	Ni	Pb	Sn	Zn
Aluminum pig	99.22	0.05	0.36	0.37	....	....	....	...	....	....
50:50 Cu-Al alloy	49.92	49.24	0.49	0.35	....	....	....	...	....	....
20:80 Si-Al alloy	79.40	0.02	1.23	19.35	....	....	....	...	....	....
25:75 Mn-Al alloy	73.76	0.12	0.82	0.85	....	24.45	....	...	....	....
15:85 Ni-Al alloy	82.67	0.04	0.46	0.27	....	....	16.56	...	....	....
Steel scrap	....	0.10 C	...	....	....	....	....	...	....	....
Magnesium	....	0.01	0.11	nil	99.88	....	....	...	....	....
Manganese	0.75	0.05	1.76	1.58	....	95.47	....	...	....	....
Nickel	....	0.20	0.44	....	....	....	98.37	...	....	....
Tin	....	nil	...	....	....	....	....	0.03	99.97	....
Zinc	....	0.24	0.45	....	....	....	....	1.93	0.26	97.12

a Analyses by C. H. Eldridge.
b Aluminum, by difference.

were made by making fixed additions of the different metals as such or in the form of intermediate alloys, to liquid alumi-

num. Certain of the zinc-containing alloys were furnished by founders, and the zinc was obtained from a founder. It was quite impure as may be seen from the analysis, and small amounts of lead are present in the zinc-containing alloys. The actual compositions agree fairly well in most cases with the intended compositions. While the desirability of extending greatly the number of alloys for test was recognized, it was found necessary, with the time available to limit the number to 40 alloys, and these include the commercially important alloys, certain alloys suggested by foundrymen, and some special alloys made up for the purpose of examining the effect of added elements upon the contraction of specific alloys. Table 12 gives the nominal and actual compositions of the alloys employed.

c.—Preparation of the Alloys

Heats of the various alloys were made up first in lots of about 10 pounds each, thoroughly stirred, sampled for chemical analysis, and poured into small pigs. The alloys were prepared by melting in a small natural-gas-fired crucible furnace, and graphite-clay crucibles of ordinary foundry grade were used as the containing vessels. In general, the aluminum was melted first, and the additive metals were introduced subsequently into the liquid aluminum, care being taken to keep the melting temperature low. Copper was introduced with 50:50 copper-aluminum alloy as the vehicle, and iron was added in the form of small clippings of light gage steel scrap. Silicon was introduced by using an intermediate 20:80 silicon-aluminum alloy furnished by the Alpax Research Laboratories, through the kindness of W. E. Mansfield. The manganese was added in the form of 25:75 manganese-aluminum alloy, previously made by the addition of pea-size commercial manganese to liquid aluminum. Nickel was introduced by the use of 15 : 85 nickel-aluminum alloy, prepared by adding commercially pure nickel sheet clippings to liquid aluminum. The magnesium was added in the form of 99.9 per cent metal, furnished by the Dow Chemical Co., and, when making additions, small pieces of the magnesium were held in the aluminum or aluminum alloy until melted. Commercially pure tin and zinc furnished by a

TABLE 12.

Chemical composition of the light alloys used in the experiments.

Alloy number	Nominal composition	Elements, per cent									
		Al[b]	Cu	Fe	Si	Mg	Mn	Ni	Pb	Sn	Zn
1	100 Al	99.20	0.04	0.42	0.34	....	....	....	....	....	.....
2	96:4 Al-Cu	94.84	4.31	0.41	0.34	....	....	....	....	....	.....
3	92:8 Al-Cu	90.92	8.14	0.41	0.53	....	....	....	....	....	.....
4	90:10 Al-Cu	88.60	10.72	0.34	0.34	....	....	....	....	....	.....
5	88:12 Al-Cu	87.17	12.07	0.40	0.36	....	....	....	....	....	.....
6	86:14 Al-Cu	85.91	13.36	0.38	0.35	....	....	....	....	....	.....
7	96:4 Al-Mg	95.19	0.03	0.36	0.28	4.14	....	....	....	....	.....
8	92:8 Al-Mg	91.23	0.03	0.45	0.26	8.03	....	....	....	....	.....
9	98.5:1.5 Al-Mn	97.56	0.05	0.39	0.32	....	1.68	....	....	....	.....
10	92:8 Al-Ni	91.71	0.10	0.36	0.29	....	....	7.54	....	....	.....
11	97:3 Al-Si	96.54	0.03	0.50	2.83	....	....	....	....	....	.....
12	90:10 Al-Si	89.28	0.05	0.78	9.89	....	....	....	....	....	.....
13	92:8 Al-Sn	90.48	0.02	0.53	0.31	....	....	8.66	....	....	.....
14	90:10 Al-Zn	88.72	0.05	0.35	0.25	....	....	....	0.12	....	10.51
15	80:20 Al-Zn	76.24	0.09	0.38	0.29	....	....	....	0.20	....	22.80
16	67:33 Al-Zn	65.61	0.10	0.37	0.27	....	....	....	0.22	....	33.43
17	90:8:2 Al-Cu-Fe	90.18	8.26	1.17	0.39	....	....	....	....	....	.....
18	88:8:4 Al-Cu-Fe	88.21	7.04	4.40	0.35	....	....	....	....	....	.....
19	91.5:8:0.5 Al-Cu-Mg	91.14	7.44	0.48	0.36	0.58	....	....	....	....	.....
20	90:8:2 Al-Cu-Mg	89.68	0.22	0.27	0.34	2.49	....	....	....	....	.....
21	97:2:1 Al-Cu-Mn	96.20	1.87	0.47	0.35	....	1.11	....	....	....	.....
22	90:8:2 Al-Cu-Mn	89.97	7.11	0.44	0.40	....	2.08	....	....	....	.....
23	85:14:1 Al-Cu-Mn	86.18	11.92	0.42	0.37	....	1.11	....	....	....	.....
24	90:8:2 Al-Cu-Ni	90.21	7.32	0.39	0.35	....	....	1.73	....	....	.....
25	85:14:1 Al-Cu-Ni	86.34	12.34	0.34	0.33	....	....	0.65	....	....	.....
26	90:8:2 Al-Cu-Si	90.31	7.07	0.61	2.01	....	....	....	....	....	.....
27	90:8:2 Al-Cu-Sn	88.91	8.22	0.47	0.31	....	....	....	....	2.09	.....
28	88:8:4 Al-Cu-Sn	87.96	7.40	0.43	0.35	....	....	....	....	3.86	.....
29	85:5:10 Al-Cu-Sn	85.26	4.72	0.45	0.22	....	....	....	....	9.35	.....
30	90:2:8 Al-Cu-Zn	89.53	2.11	0.45	0.30	....	....	....	....	....	7.61
31	90:8:2 Al-Cu-Zn	89.30	7.91	0.44	0.34	....	....	....	....	....	2.01
32	85:3:12 Al-Cu-Zn	85.39	2.85	0.45	0.26	....	....	....	....	....	11.05
33	77:3:20 Al-Cu-Zn	72.13	3.24	0.49	0.35	....	....	....	0.22	....	23.57
34	66:1:33 Al-Mn-Zn	66.85	0.07	0.52	0.23	....	1.08	....	0.58	....	30.67
35	95.5:3:1:0.5 Al-Cu-Fe-Mg	94.57	3.05	1.41	0.40	0.57	....	....	....	....	.....
36	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	95.41	1.25	0.35	0.35	1.39	....	1.25	....	....	.....
37	92.5:4:1.5:2 Al-Cu-Mg-Ni	90.86	5.02	0.36	0.33	1.47	....	1.96	....	....	.....
38	91:7:1:1 Al-Cu-Sn-Zn	89.96	7.18	0.42	0.34	....	....	....	....	0.98	1.12
39	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	87.47	6.08	0.47	0.35	....	1.07	1.15	....	....	3.51
40	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	76.81	2.94	0.46	0.42	0.33	0.61	....	0.34	....	18.09
41	Duralumin	94.11	3.95	0.46	0.36	0.45	0.67	nil	....	....	nil

a Analyses by C. H. Eldridge. *b* Aluminum, by difference.

foundry were employed for making additions of these elements. As will be noted, the zinc was quite impure, but several of the zinc-containing alloys were furnished by a foundry, and in making up other zinc-containing alloys the zinc employed by the foundry was used.

d.—Method of Experiment

It was pointed out previously that there is a considerable dearth of reported measurements for the linear contraction of the light alloys, and some of those given in the literature are of doubtful value because of an absence of detailed information as to the conditions of experiment, particularly as to the size of section, pouring temperature, and chemical composition of the alloys. In the present experiments, it was decided to examine the effect of the pouring temperature and size of section upon the linear contraction of the alloys, and since a large number of measurements were necessary in the case of the former, it was thought best to make determinations on casting into graphite molds in the laboratory, varying the pouring temperature over a wide range. Accordingly, experiments were carried out by pouring the alloys at various temperatures in the range 650 to 1,000 degrees Cent., into graphite molds, keeping all other conditions constant. In order to examine the effect of the size of section, measurements were made on bars cast in sand molds, employing three different sizes of section but of the same length.

1. *Method of Experiment for Chill-Cast Bars.* In the first set of experiments, the series of alloys was cast into chill molds (machined Acheson graphite) of known definite dimensions, and then the lengths of the resulting bars were measured after cooling to room temperature. In all, about 1,800 bars were poured, covering the 40 alloys, in the range of pouring temperature 650 to 1,000 degrees Cent., at 25 degrees Cent., intervals. Bars were poured in duplicate at each pouring temperature, and when the results did not agree, additional bars were poured. The molds were at room temperature on pouring, and each mold was poured just full.

The alloys were melted in the small natural-gas-fired crucible furnace, mentioned previously as being used in making

up the alloys, and the melting and pouring temperatures were taken with a Wilson-Mauelen pyod (baby type). The pouring temperatures were held accurate to ±5 degrees Cent. In casting the bars, a heat of an alloy was brought up to slightly above the desired temperature, and then poured at the required temperature. Some runs were made by pouring a number of bars from one heat brought up to a fairly high temperature, and then cooled between successive pours, so as to examine the effect of cooling from a higher temperature to a lower pouring temperature upon the contraction. The measurements indicated that the melting temperature had no effect upon the contraction for a given pouring temperature, and it is here assumed that this is true, pending exact proof, although theoretically a high melting temperature would be expected to give less contraction than a low melting temperature for a given pouring temperature in each case since overheated melts readily remain saturated with gas, and gas evolution at the moment of freezing would tend to lessen the contraction.

The molds employed consisted of split molds of the form shown in the sketch of Fig. 1. These were machined from slabs of Acheson graphite, and the inside cavity had the dimensions 1,000-inch square by 6,000 inches long. The pouring gate was 0.5-inch high and 1.0-inch diameter. A number of different molds were employed in the tests, and the size of the mold cavity in each was measured and checked before and after each bar was poured; the internal dimensions remained constant within ± 0.001 inch, and any necessary corrections were applied in the calculation of the results. Acheson graphite was chosen as a suitable material for the molds because it is readily machined and has a low coefficient of expansion. The effects of repeated heating and cooling on graphite were known to be slight, and since the accepted value for the coefficient of thermal expansion of the material is

$$10^{-6}\ \text{alpha} = 0.55 + 0.0032t,$$

as determined by Day and Sosman, any expansion that occurs on pouring hot metal up to 1,000 degrees Cent., is negligible when referred to linear contraction measurements.

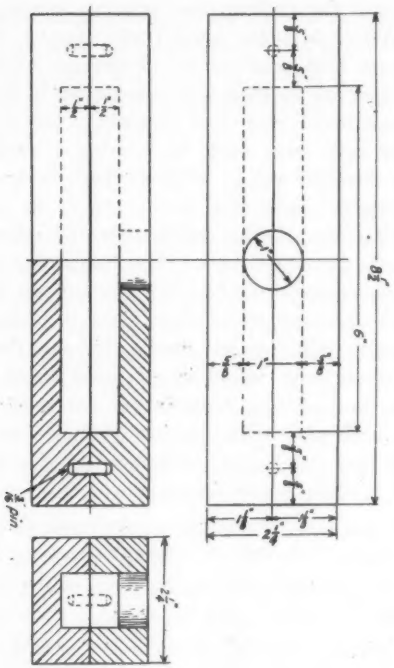

FIG. 1.—SKETCH SHOWING FORM OF GRAPHITE MOLD USED FOR DETERMINATION OF LINEAR CONTRACTION

Measurements of the cast bars were made with a 6-inch vernier caliper to ± 0.0005 inch, and calculation was made for the contraction in per cent, in inch per foot, and in terms of the pattern-maker's shrinkage. After freezing in the molds, the bars were removed and cooled to room temperature, by standing in the air, before measurement.

2. *Method of Experiment for Sand-Cast Bars.* The same alloys used in the experiments on linear contractions in chill molds were employed for measurements on pouring into sand molds. As has been stated, while the contraction is a function of a number of factors including the pouring temperature, size

of test-bar section, and method of molding (size of gates, whether risers are used, etc.) it was not possible to investigate the effects of all factors, but examination was made of the effect of size of section and the pouring temperature. Bars were cast in sand molds, in the various alloys, from wooden patterns of the following three sizes; (1) 0.5-inch square by 12

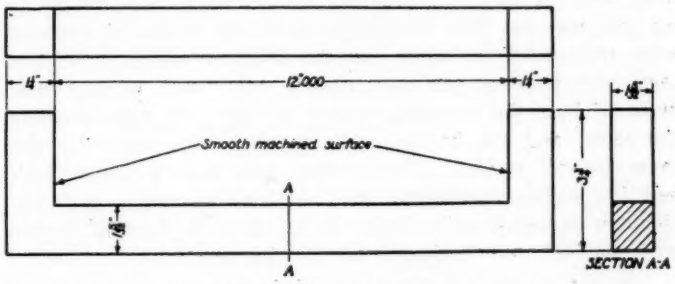

FIG. 2.—SKETCH SHOWING FORM OF TEMPLATE USED IN POURING BARS IN SAND MOLDS

inches long; (2) 1.0-inch square by 12 inches long; and (3) 0.5 by 1.0 inch by 12 inches long. The alloys were cast at two temperatures in the case of the 0.5-inch and 1.0-inch square bars; viz., a high pouring temperature (900 degrees Cent.) and a low pouring temperature (700 degrees Cent). Bars were poured in duplicate, and when the results did not agree, additional bars were poured.

The alloys were melted in a natural-gas-fired crucible furnace, in the foundry, using graphite-clay crucibles as the containing vessels, and the melting and pouring temperatures were controlled as described above for the bars cast in chill molds. All conditions of molding were held as constant as possible throughout, and some few experiments were made where certain molding factors were varied purposely.

Bars of the sizes mentioned were poured in sand molds between the faces of a cast-iron template, and the lengths were

measured when the bars cooled to room temperature. The template was 12.000 inches between the faces and of the form shown in the sketch of Fig. 2. The method of molding is shown in detail in the sketch of Fig. 3. In molding, the bar pattern and the template were molded together in the drag on the parting line with the cope; the pattern was then removed, leaving the template in place, and the mold was closed and poured. No risers were used; the bars were vented through the drag, and the alloy was poured into the mold until the pouring gate was just full. Conditions as to the method of molding were maintained the same for the different alloys, i. e., the same size pouring gate and runner were used, attempt was made to hold the moisture content of the sand approximately the same, and the hardness of ramming was practically the same for all molds. The pouring gate was 4 inches high and 1¼ inches in diameter, and the lead-off runner was 1½ inches wide and 2 inches long. In all cases the lead-off runner was one-half the thickness of the bar.

Fig. 3 (section A-A) shows the mold cavity for the 1.0-inch square bar. The bar of 0.5 by 1.0 inch cross section was molded with the 0.5-inch side up.

The templates were made of gray cast iron machined to size, and the distance between the faces was 12.000 inches. There was found to be no measurable variation in distance between the faces of different templates or variation in the distances after repeated use. After pouring, the bars were shaken out of the molds as soon as frozen, then cooled in air to room temperature, and measured as to length with a 12-inch vernier caliper. Moisture determinations were made on the sand, and the water content varied between the limits 7.1 to 7.8 per cent. The sand was cut and wetted so that it hung together well in the hand but not too firmly.

D.—Results of the Linear-Contraction Experiments

a.—Linear Contraction of the Alloys in Chill Molds

Summaries of the results of the measurements made on the linear contraction of the alloys in chill molds (Acheson graphite) are given in Tables 13 and 14. Table 13 gives figures

for aluminum and 40 alloys as to the mean linear contraction over the pouring-temperature range employed, as well as the mean linear contraction on pouring at the ordinary temperature (700 to 800 degrees Cent.). Owing to lack of space, it is not possible to present detailed figures for the contraction of

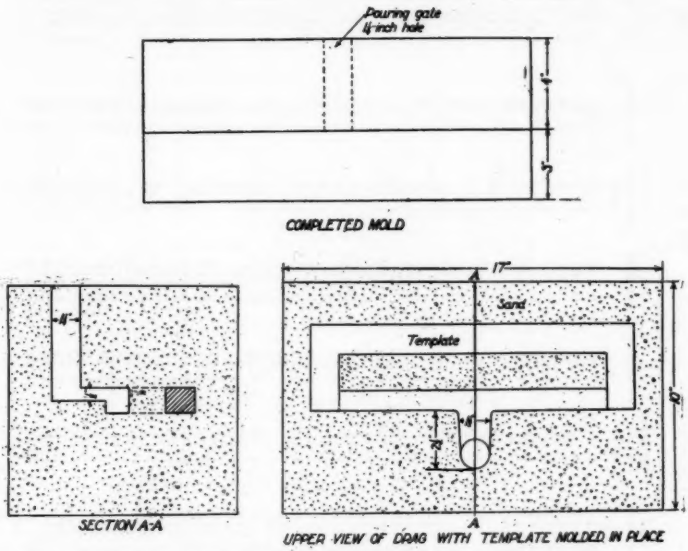

FIG. 3.—SKETCH SHOWING METHOD OF MOLDING BARS IN SAND MOLDS

the various alloys on pouring at different temperatures (25 degrees Cent. intervals) in the range employed (650 to 1,000 degrees Cent.). Figures are given in the table for the variation in contraction over the pouring-temperature range employed and for the difference in per cent between the greatest and least contraction for the different alloys. It will be seen that the greatest difference in contraction (between the high and low values) is 0.16 per cent for aluminum, while the least is 0.05 per cent for the 92:8 aluminum-copper alloy and for the 85:14:1 aluminum-copper-nickel alloy. The average difference

TABLE 13.

Linear contraction of 41 light aluminum alloys poured in graphite molds; summarized results.

Alloy number	Nominal composition	Mean linear contraction in the range of pouring temperature of 650° to 1,000° C.			Mean linear contraction at the ordinary pouring temperature, 700° to 800° C.			Contraction range, 650° to 1,000° C.	Total difference between greatest and least contraction
		Inch per foot	Pattern-maker's scale	Per cent	Inch per foot	Pattern-maker's scale	Per cent	Per cent	Per cent
1	100 Al	0.196	1/60	1.63	0.198	1/60	1.65	1.52–1.68	0.16
2	96:4 Al-Cu	0.162	1/73	1.35	0.163	1/73	1.36	1.30–1.38	0.08
3	92:8 Al-Cu	0.155	1/77	1.29	0.161	1/74	1.34	1.22–1.37	0.15
4	90:10 Al-Cu	0.148	1/80	1.23	0.149	1/80	1.24	1.18–1.28	0.10
5	88:12 Al-Cu	0.143	1/83	1.19	0.143	1/83	1.19	1.13–1.25	0.12
6	86:14 Al-Cu	0.143	1/83	1.19	0.144	1/82	1.20	1.17–1.23	0.06
7	96:4 Al-Mg	0.164	1/72	1.37	0.166	1/71	1.38	1.33–1.40	0.07
8	92:8 Al-Mg	0.139	1/85	1.16	0.138	1/86	1.15	1.12–1.22	0.10
9	98.5:1.5 Al-Mn	0.193	1/61	1.61	0.193	1/61	1.61	1.57–1.65	0.08
10	92:8 Al-Ni	0.172	1/69	1.43	0.170	1/69	1.42	1.40–1.45	0.05
11	97:3 Al-Si	0.151	1/78	1.26	0.154	1/77	1.28	1.22–1.30	0.08
12	90:10 Al-Si	0.134*a*	1/88	1.12	0.133	1/89	1.11	1.07–1.18	0.11
13	92:8 Al-Sn	0.164	1/72	1.37	0.166	1/71	1.38	1.32–1.43	0.11
14	90:10 Al-Zn	0.166	1/71	1.38	0.164	1/72	1.37	1.32–1.42	0.10
15	80:20 Al-Zn	0.146	1/81	1.22	0.145	1/82	1.21	1.17–1.27	0.10
16	67:33 Al-Zn	0.117	1/103	0.96	0.114	1/104	0.95	0.92–1.00	0.08
17	90:8:2 Al-Cu-Fe	0.152	1/78	1.27	0.155	1/77	1.29	1.22–1.32	0.10
18	88:8:4 Al-Cu-Fe	0.142*b*	1/84	1.18	0.145*c*	1/82	1.21	1.13–1.22*b*	0.09
19	91.5:8:0.5 Al-Cu-Mg	0.151	1/78	1.26	0.152	1/78	1.27	1.17–1.30	0.13
20	90:8:2 Al-Cu-Mg	0.128	1/92	1.07	0.130	1/92	1.08	1.03–1.15	0.12
21	97:2:1 Al-Cu-Mn	0.175	1/67	1.46	0.176	1/67	1.47	1.42–1.50	0.08
22	90:8:2 Al-Cu-Mn	0.168	1/70	1.40	0.168	1/70	1.40	1.37–1.43	0.06
23	85:14:1 Al-Cu-Mn	0.151	1/78	1.26	0.151	1/78	1.26	1.22–1.28	0.06
24	90:8:2 Al-Cu-Ni	0.146	1/81	1.22	0.150	1/79	1.25	1.15–1.28	0.13
25	85:14:1 Al-Cu-Ni	0.150	1/79	1.25	0.149	1/80	1.24	1.22–1.27	0.05
26	90:8:2 Al-Cu-Si	0.138	1/86	1.15	0.140	1/84	1.17	1.10–1.22	0.12
27	90:8:2 Al-Cu-Sn	0.146	1/81	1.22	0.151	1/78	1.26	1.15–1.28	0.13
28	88:8:4 Al-Cu-Sn	0.149	1/80	1.24	0.149	1/80	1.24	1.17–1.28	0.11
29	85.5:10 Al-Cu-Sn	0.148	1/80	1.23	0.149	1/80	1.24	1.17–1.27	0.10
30	90:2:8 Al-Cu-Zn	0.168	1/70	1.40	0.168	1/70	1.40	1.37–1.45	0.08
31	90:8:2 Al-Cu-Zn	0.155	1/77	1.29	0.155	1/77	1.29	1.23–1.33	0.10
32	85:3:12 Al-Cu-Zn	0.150	1/79	1.25	0.151	1/78	1.26	1.17–1.32	0.15
33	77:3:20 Al-Cu-Zn	0.142	1/84	1.18	0.139	1/85	1.16	1.15–1.22	0.07
34	66:1:33 Al-Mn-Zn	0.132	1/90	1.10	0.133	1/89	1.11	1.07–1.15	0.08
35	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.170	1/69	1.42	0.172	1/69	1.43	1.37–1.47	0.10
36	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.155	1/77	1.29	0.154	1/77	1.28	1.22–1.33	0.11
37	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.143	1/84	1.19	0.143	1/83	1.19	1.12–1.23	0.11
38	91:7:1:1 Al-Cu-Sn-Zn	0.156	1/75	1.30	0.157	1/75	1.31	1.23–1.40	0.07
39	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.145	1/81	1.21	0.146	1/81	1.22	1.17–1.25	0.08
40	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.139	1/85	1.16	0.140	1/84	1.17	1.10–1.22	0.08
41	Duralumin	0.154	1/77	1.28	0.156	1/76	1.30	1.25–1.32	0.07

a In the pouring-temperature range 600° to 1,000° C.
b In the pouring-temperature range 875° to 1,000° C.
c In the pouring-temperature range 900° to 950° C.

TABLE 14.

Linear contraction of 41 light aluminum alloys poured in graphite molds, arranged in the order of contraction, and using the mean contraction values at the ordinary pouring temperature, 700° to 800° C.

Order of contraction	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
Greatest				
1	100 Al	0.198	1/60	1.65
2	98.5:1.5 Al-Mn	0.193	1/61	1.61
3	97:2:1 Al-Cu-Mn	0.176	1/67	1.47
4	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.172	1/69	1.43
5	92:8 Al-Ni	0.170	1/69	1.42
6	90:8:2 Al-Cu-Mn	0.168	1/70	1.40
7	90:2:8 Al-Cu-Zn	0.168	1/70	1.40
8	96:4 Al-Mg	0.166	1/71	1.38
9	92:8 Al-Sn	0.166	1/71	1.38
10	90:10 Al-Zn	0.164	1/72	1.37
11	96:4 Al-Cu	0.163	1/73	1.36
12	92:8 Al-Cu	0.161	1/74	1.34
13	91:7:1:1 Al-Cu-Sn-Zn	0.157	1/75	1.31
14	Duralumin	0.156	1/76	1.30
15	90:8:2 Al-Cu-Zn	0.155	1/77	1.29
16	90:8:2 Al-Cu-Fe	0.155	1/77	1.29
17	97:3 Al-Si	0.154	1/77	1.28
18	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.154	1/77	1.28
19	91.5:8:0.5 Al-Cu-Mg	0.152	1/78	1.27
20	90:8:2 Al-Cu-Sn	0.151	1/78	1.26
21	85:3:12 Al-Cu-Zn	0.151	1/78	1.26
22	85:14:1 Al-Cu-Mn	0.151	1/78	1.26
23	90:8:2 Al-Cu-Ni	0.150	1/79	1.25
24	90:10 Al-Cu	0.149	1/80	1.24
25	85:14:1 Al-Cu-Ni	0.149	1/80	1.24
26	85:5:10 Al-Cu-Sn	0.149	1/80	1.24
27	88:8:4 Al-Cu-Sn	0.149	1/80	1.24
28	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.146	1/81	1.22
29	88:8:4 Al-Cu-Fe[a]	0.145	1/82	1.21
30	80:20 Al-Zn	0.145	1/82	1.21
31	86:14 Al-Cu	0.144	1/82	1.20
32	88:12 Al-Cu	0.143	1/83	1.19
33	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.143	1/83	1.19
34	90:8:2 Al-Cu-Si	0.140	1/84	1.17
35	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.140	1/84	1.17
36	77:3:20 Al-Cu-Zn	0.139	1/85	1.16
37	92:8 Al-Mg	0.138	1/86	1.15
38	90:10 Al-Si	0.133	1/89	1.11
39	66:1:33 Al-Mn-Zn	0.133	1/89	1.11
40	90:8:2 Al-Cu-Mg	0.130	1/92	1.08
41	67:33 Al-Zn	0.114	1/104	0.95
Least				

[a] In the pouring-temperature range 900° to 950° C.

in contraction between the highest and the lowest values is 0.095 per cent. The effect of pouring-temperature variation upon the measured linear contraction is thus plainly established. It will be seen from the table that in general the mean linear contraction for the separate alloys over the pouring-temperature range 650 to 1,000 Cent., is about the same as that in the range 700 to 800 degrees Cent.

In Table 14, the alloys are arranged in their order of contraction, the alloy having the greatest contraction being given first. The values are for the mean linear contraction in the pouring-temperature range 700 to 800 degrees Cent., and these lie between 1.65 per cent for substantially pure aluminum and 0.95 per cent for the 67:33 aluminum-zinc alloy. Eighteen of the alloys have contraction values within the limits 1.20 to 1.30 per cent, and these include a number of the present commercially useful ones. The results of the experimental measurements on the contraction of the alloys in chill molds will be taken up at length in a subsequent section of the paper under the caption, "General Discussion of the Experiments, Effect of Various Factors on Contraction, and Conclusions."

b.—Linear Contraction of the Alloys in Sand Molds

The same alloys in the above experiments on the linear contraction on pouring into graphite molds were employed in a series of runs made on bars poured in sand molds. Summaries of the results of the measurements are given in Tables 15 to 20 inclusive. Table 15 shows a comparison of the linear contraction of 0.5-inch square bars poured at 700 and at 900 degrees Cent., and the differences in contraction are indicated. The average difference in contraction for the alloys on pouring at the two temperatures is 0.059 per cent. The range of contraction for the alloys cast at 700 degrees Cent. is from 1.22 per cent for the 90:8:2 aluminum-copper-magnesium alloy to 1.68 per cent for substantially pure aluminum and for 98.5:1.5 aluminum-manganese alloy. The range of contraction for the alloys cast at 900 degrees Cent. is from 1.16 per cent for the 90:8:2

TABLE 15.

Summarized results of linear contraction of the alloys pouredi n sand molds; 0.5-inch square bars.

Alloy number	Nominal composition	Linear contraction of bars poured at 700°C.			Linear contraction of bars poured at 900°C.			Excess of per cent linear contraction of bars poured at 700°C. over those poured at 900° C.
		Inch per foot	Pattern-maker's scale	Per cent	Inch per foot	Pattern-maker's scale	Per cent	
1	100 Al	0.201	1/59	1.68	0.185	1/64	1.54	+0.14
2	96:4 Al-Cu	0.172	1/69	1.43	0.172	1/69	1.43	0.00
3	92:8 Al-Cu	0.170	1/69	1.42	0.160	1/74	1.33	+0.09
4	90:10 Al-Cu	0.168	1/70	1.40	0.154	1/77	1.28	+0.12
5	88:12 Al-Cu	0.162	1/73	1.35	0.150	1/79	1.25	+0.10
6	86:14 Al-Cu	0.156	1/76	1.30	0.154	1/77	1.28	+0.02
7	96:4 Al-Mg	0.176	1/67	1.47	0.180	1/66	1.50	−0.03
8	92:8 Al-Mg	0.147	1/81	1.23	0.149	1/80	1.24	−0.01
9	98.5:1.5 Al-Mn	0.201	1/59	1.68	0.201	1/59	1.68	0.00
10	92:8 Al-Ni	0.193	1/61	1.61	0.185	1/64	1.54	+0.07
11	97:3 Al-Si	0.174	1/68	1.45	0.161	1/74	1.34	+0.11
12	90:10 Al-Si	0.172	1/69	1.43	0.154	1/77	1.28	+0.15
13	92:8 Al-Sn	0.179	1/66	1.49	0.157	1/75	1.31	+0.18
14	90:10 Al-Zn	0.184	1/64	1.53	0.173	1/68	1.44	+0.09
15	80:20 Al-Zn	0.170	1/69	1.42	0.159	1/74	1.33	+0.08
16	67:33 Al-Zn	0.153	1/77	1.28	0.150	1/79	1.25	+0.03
17	90:8:2 Al-Cu-Fe	0.172	1/69	1.43	0.174	1/68	1.45	−0.02
18	88:8:4 Al-Cu-Fe	0.168*a*	1/70	1.40	0.158*b*	1/75	1.32	+0.08
19	91.5:8:0.5 Al-Cu-Mg	0.156	1/76	1.30	0.148	1/80	1.23	+0.07
20	90:8:2 Al-Cu-Mg	0.146	1/81	1.22	0.139	1/85	1.16	+0.06
21	97:2:1 Al-Cu-Mn	0.196	1/60	1.63	0.196	1/60	1.63	0.00
22	90:8:2 Al-Cu-Mn	0.178	1/67	1.48	0.170	1/69	1.42	+0.06
23	85:14:1 Al-Cu-Mn	0.163	1/73	1.36	0.156	1/76	1.30	+0.06
24	90:8:2 Al-Cu-Ni	0.168	1/70	1.40	0.162	1/73	1.35	+0.05
25	85:14:1 Al-Cu-Ni	0.169	1/70	1.41	0.165	1/72	1.38	+0.03
26	90:8:2 Al-Cu-Si	0.149	1/80	1.24	0.143	1/83	1.19	+0.05
27	90:8:2 Al-Cu-Sn	0.167	1/71	1.39	0.150	1/79	1.25	+0.14
28	88:8:4 Al-Cu-Sn	0.157	1/75	1.31	0.150	1/79	1.25	+0.06
29	85:5:10 Al-Cu-Sn	0.156	1/76	1.30	0.152	1/78	1.27	+0.03
30	90:2:8 Al-Cu-Zn	0.179	1/66	1.49	0.170	1/69	1.42	+0.07
31	90:8:2 Al-Cu-Zn	0.164	1/72	1.37	0.150	1/79	1.25	+0.12
32	85:3:12 Al-Cu-Zn	0.161	1/74	1.34	0.166	1/71	1.38	−0.04
33	77:3:20 Al-Cu-Zn	0.162	1/73	1.35	0.159	1/74	1.33	+0.02
34	66:1:33 Al-Mn-Zn	0.155	1/77	1.29	0.154	1/77	1.28	+0.01
35	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.180	1/66	1.50	0.173	1/68	1.44	+0.06
36	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.178	1/67	1.48	0.167	1/71	1.39	+0.09
37	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.161	1/74	1.34	0.161	1/74	1.34	0.00
38	91:7:1:1 Al-Cu-Sn-Zn	0.169	1/70	1.41	0.156	1/76	1.30	+0.11
39	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.172	1/69	1.43	0.166	1/72	1.37	+0.06
40	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.156	1/76	1.30	0.155	1/77	1.29	+0.01
41	Duralumin	0.180	1/66	1.50	0.168	1/70	1.40	+0.10

a Poured at 850° C. *b* Poured at 950° C.

aluminum-copper-magnesium alloy to 1.68 per cent for the 98.5:1.5 aluminum-manganese alloy. A number of possible anomalies are revealed by these summarized data as compared with the results obtained by casting in chill molds, but sufficient data are not in hand to permit explanation of the variations.

Table 16 gives a summarized comparison of the linear contraction of the 1.0-inch square bars cast at 700 and 900 degrees Cent., and the differences in contraction are indicated. The average difference in contraction for the alloys on pouring at the two temperatures indicated is 0.021 per cent. The range of contraction for the alloys poured at 700 degrees Cent. is from 1.24 per cent for the 90:8:2 aluminum-copper-magnesium alloy to 1.75 per cent for the 98.5:1.5 aluminum-manganese alloy. The range of contraction for the alloys poured at 900 degrees Cent. is from 1.23 per cent for the 90:8:2 aluminum-copper-silicon alloy to 1.80 per cent for the 98.5:1.5 aluminum-manganese alloy. Table 17 gives a summary of the linear-contraction results of the 0.5 by 1.0 inch bars poured at 700 degrees Cent.

In Tables 18, 19 and 20, the alloys are arranged in their order of contraction, the alloy with the greatest contraction being given first, for bars poured at 700 degrees Cent. In Table 18, where the figures for the 0.5-inch square bars are listed, the values vary from 1.68 per cent for both aluminum and the 98.5:1.5 aluminum-manganese alloy to 1.22 per cent for the 90:8:2 aluminum-copper-magnesium alloy. Under the experimental conditions, seventeen of the alloys have contraction values within the limits 1.35 to 1.45 per cent. In Table 19, where the figures for the 1.0-inch square bars poured at 700 degrees Cent. are listed, the values vary from 1.75 per cent for the 98.5:1.5 aluminum-manganese alloy to 1.23 per cent for the 92:2 aluminum-magnesium alloy. In Table 20, where the values for the 0.5 by 1.0-inch bars poured at 700 degrees Cent. are listed, the values vary from 1.68 per cent for the

TABLE 16.

Summarized results of linear contraction of the alloys poured in sand molds, 1.0-inch square bars.

Alloy number	Nominal composition	Linear contraction of bars poured at 700°C.			Linear contraction of bars poured at 900°C.			Excess of per cent linear contraction of bars poured at 700°C. over those poured at 900° C.
		Inch per foot	Pattern-maker's scale	Per cent	Inch per foot	Pattern-maker's scale	Per per cent	
1	100 Al	0.202	1/59	1.68	0.192	1/62	1.60	+0.08
2	96:4 Al-Cu	0.188	1/63	1.57	0.178	1/67	1.48	+0.09
3	92:8 Al-Cu	0.172	1/69	1.43	0.168	1/70	1.40	+0.03
4	90:10 Al-Cu	0.168	1/70	1.40	0.164	1/72	1.37	+0.03
5	88:12 Al-Cu	0.168	1/70	1.40	0.152	1/78	1.27	+0.13
6	86:14 Al-Cu	0.160	1/74	1.33	0.158	1/75	1.32	+0.01
7	96:4 Al-Mg	0.179	1/66	1.49	0.180	1/66	1.50	−0.01
8	92:8 Al-Mg	0.147	1/81	1.23	0.152	1/78	1.27	−0.04
9	98.5:1.5 Al-Mn	0.210	1/56	1.75	0.216	1/55	1.80	−0.05
10	92:8 Al-Ni	0.192	1/62	1.60	0.192	1/62	1.60	0.00
11	97:3 Al-Si	0.175	1/67	1.46	0.166	1/71	1.38	+0.08
12	90:10 Al-Si	0.172	1/69	1.43	0.162	1/73	1.35	+0.08
13	92:8 Al-Sn	0.184	1/64	1.53	0.178	1/67	1.48	+0.05
14	90:10 Al-Zn	0.189	1/62	1.58	0.186	1/64	1.55	+0.03
15	80:20 Al-Zn	0.167	1/71	1.39	0.171	1/69	1.43	−0.04
16	67:33 Al-Zn	0.152	1/78	1.27	0.152	1/78	1.27	0.00
17	90:8:2 Al-Cu-Fe	0.170	1/69	1.42	0.172	1/69	1.43	−0.01
18	88:8:4 Al-Cu-Fe	0.170[a]	1/69	1.42	0.168[b]	1/70	1.40	+0.02
19	91.5:8:0.5 Al-Cu-Mg	0.166	1/71	1.38	0.167	1/71	1.39	−0.01
20	90:8:2 Al-Cu-Mg	0.149	1/80	1.24	0.148	1/80	1.23	+0.01
21	97.2:1 Al-Cu-Mn	0.198	1/60	1.65	0.192	1/62	1.60	+0.05
22	90:8:2 Al-Cu-Mn	0.185	1/64	1.54	0.178	1/67	1.48	+0.06
23	85:14:1 Al-Cu-Mn	0.165	1/72	1.38	0.165	1/72	1.38	0.00
24	90:8:2 Al-Cu-Ni	0.173	1/68	1.44	0.166	1/71	1.38	+0.06
25	85:14:1 Al-Cu-Ni	0.167	1/71	1.39	0.167	1/71	1.39	0.00
26	90:8:2 Al-Cu-Si	0.159	1/74	1.33	0.147	1/81	1.23	+0.10
27	90:8:2 Al-Cu-Sn	0.170	1/69	1.42	0.165	1/72	1.38	+0.04
28	88:8:4 Al-Cu-Sn	0.160	1/74	1.33	0.162	1/73	1.35	−0.02
29	85:5:10 Al-Cu-Sn	0.163	1/73	1.36	0.158	1/75	1.32	+0.04
30	90:2:8 Al-Cu-Zn	0.179	1/66	1.49	0.180	1/66	1.50	−0.01
31	90:8:2 Al-Cu-Zn	0.170	1/69	1.42	0.171	1/69	1.43	−0.01
32	85:3:12 Al-Cu-Zn	0.171	1/69	1.43	0.175	1/67	1.46	−0.03
33	77:3:20 Al-Cu-Zn	0.166	1/71	1.38	0.162	1/73	1.35	+0.03
34	66:1:33 Al-Mn-Zn	0.156	1/76	1.30	0.150	1/79	1.25	+0.05
35	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.185	1/64	1.54	0.184	1/64	1.53	+0.01
36	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.177	1/67	1.48	0.179	1/66	1.49	−0.01
37	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.164	1/72	1.37	0.165	1/72	1.38	−0.01
38	91:7:1:1 Al-Cu-Sn-Zn	0.173	1/68	1.44	0.173	1/68	1.44	0.00
39	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.172	1/69	1.43	0.173	1/68	1.44	−0.01
40	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.162	1/73	1.35	0.161	1/74	1.34	+0.01
41	Duralumin	0.184	1/64	1.53	0.179	1/66	1.49	+0.06

a Poured at 850° C. *b* Poured at 950° C.

TABLE 17.

Summarized results of linear contraction of the alloys poured in sand molds; 0.5 by 1.0-inch bars.

Alloy number	Nominal composition	Linear contraction of the bars, poured at 700 degrees Cent.		
		Inch per foot	Pattern-maker's scale	Per cent
1	100 Al	0.197	1/60	1.64
2	96:4 Al-Cu	0.176	1/67	1.47
3	92:8 Al-Cu	0.164	1/72	1.37
4	90:10 Al-Cu	0.167	1/71	1.39
5	88:12 Al-Cu	0.164	1/72	1.37
6	86:14 Al-Cu	0.160	1/74	1.33
7	96:4 Al-Mg	0.179	1/66	1.49
8	92:8 Al-Mg	0.146	1/81	1.22
9	98.5:1.5 Al-Mn	0.202	1/59	1.68
10	92:8 Al-Ni	0.190	1/62	1.58
11	97:3 Al-Si	0.172	1/69	1.43
12	90:10 Al-Si	0.170	1/69	1.42
13	92:8 Al-Sn	0.180	1/66	1.50
14	90:10 Al-Zn	0.185	1/64	1.54
15	80:20 Al-Zn	0.165	1/72	1.38
16	67:33 Al-Zn	0.152	1/78	1.27
17	90:8:2 Al-Cu-Fe	0.178	1/67	1.48
18	88:8:4 Al-Cu-Fe	0.169*a*	1/70	1.41
19	91.5:8:0.5 Al-Cu-Mg	0.156	1/76	1.30
20	90:8:2 Al-Cu-Mg	0.147	1/81	1.23
21	97:2:1 Al-Cu-Mn	0.198	1/60	1.65
22	90:8:2 Al-Cu-Mn	0.173	1/68	1.44
23	85:14:1 Al-Cu-Mn	0.161	1/74	1.34
24	90:8:2 Al-Cu-Ni	0.168	1/70	1.40
25	85:14:1 Al-Cu-Ni	0.171	1/69	1.43
26	90:8:2 Al-Cu-Si	0.152	1/78	1.27
27	90:8:2 Al-Cu-Sn	0.165	1/72	1.38
28	88:8:4 Al-Cu-Sn	0.162	1/73	1.35
29	85:5:10 Al-Cu-Sn	0.154	1/77	1.28
30	90:2:8 Al-Cu-Zn	0.179	1/66	1.49
31	90:8:2 Al-Cu-Zn	0.160	1/74	1.33
32	85:3:12 Al-Cu-Zn	0.156	1/76	1.30
33	77:3:20 Al-Cu-Zn	0.160	1/74	1.33
34	66:1:33 Al-Mn-Zn	0.155	1/77	1.29
35	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.182	1/65	1.52
36	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.178	1/67	1.48
37	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.164	1/72	1.37
38	91:7:1:1 Al-Cu-Sn-Zn	0.168	1/70	1.40
39	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.169	1/70	1.41
40	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.162	1/73	1.35
41	Duralumin	0.184	1/64	1.53

a Poured at 850 degrees C.

98.5:1.5 aluminum-manganese alloy to 1.22 per cent for the 92:8 aluminum-magnesium alloy. The results of the experi-

TABLE 18.

Linear contraction of 41 light aluminum alloys, 0.5-inch square bars poured at 700° C. in sand molds, arranged in the order of contract on.

Order of contraction	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
Greatest.				
1	100 Al	0.201	1/59	1.68
2	98.5:1.5 Al-Mn	0.201	1/59	1.68
3	97:2:1 Al-Cu-Mn	0.196	1/60	1.63
4	92:8 Al-Ni	0.193	1/61	1.61
5	90:10 Al-Zn	0.184	1/64	1.53
6	Duralumin	0.180	1/66	1.50
7	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.180	1/66	1.50
8	90:2:8 Al-Cu-Zn	0.179	1/66	1.49
9	92:8 Al-Sn	0.179	1/66	1.49
10	90:8:2 Al-Cu-Mn	0.178	1/67	1.48
11	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.178	1/67	1.48
12	96:4 Al-Mg	0.176	1/67	1.47
13	97:3 Al-Si	0.174	1/68	1.45
14	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.172	1/69	1.43
15	90:8:2 Al-Cu-Fe	0.172	1/69	1.43
16	90:10 Al-Si	0.172	1/69	1.43
17	96:4 Al-Cu	0.172	1/69	1.43
18	92:8 Al-Cu	0.170	1/69	1.42
19	80:20 Al-Zn	0.170	1/69	1.42
20	85:14:1 Al-Cu-Ni	0.169	1/70	1.41
21	91:7:1:1 Al-Cu-Sn-Zn	0.169	1/70	1.41
22	90:10 Al-Cu	0.168	1/70	1.40
23	88:8:4 Al-Cu-Fe [a]	0.168	1/70	1.40
24	90:8:2 Al-Cu-Ni	0.168	1/70	1.40
25	90:8:2 Al-Cu-Sn	0.167	1/71	1.39
26	90:8:2 Al-Cu-Zn	0.164	1/72	1.37
27	85:14:1 Al-Cu-Mn	0.163	1/73	1.36
28	88:12 Al-Cu	0.162	1/73	1.35
29	77:3:20 Al-Cu-Zn	0.162	1/73	1.35
30	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.161	1/74	1.34
31	85:3:12 Al-Cu-Zn	0.161	1/74	1.34
32	88:8:4 Al-Cu-Sn	0.157	1/75	1.31
33	86:14 Al-Cu	0.156	1/76	1.30
34	91.5:8:0.5 Al-Cu-Mg	0.156	1/76	1.30
35	85:5:10 Al-Cu-Sn	0.156	1/76	1.30
36	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.156	1/76	1.30
37	66:1:33 Al-Mn-Zn	0.155	1/77	1.29
38	67:33 Al-Zn	0.153	1/77	1.28
39	90:8:2 Al-Cu-Si	0.149	1/80	1.24
40	92:8 Al-Mg	0.147	1/81	1.23
41	90:8:2 Al-Cu-Mg	0.146	1/81	1.22
Least				

[a] Poured at 850° C.

TABLE 19.

Linear contraction of 41 light aluminum alloys, 1.0-inch square bars poured at 700° C., in sand molds, arranged in the order of contraction.

Order of contraction	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
Greatest				
1	98.5:1.5 Al-Mn	0.210	1/56	1.75
2	100 Al	0.202	1/59	1.68
3	97:2:1 Al-Cu-Mn	0.198	1/60	1.65
4	92:8 Al-Ni	0.192	1/62	1.60
5	90:10 Al-Zn	0.189	1/62	1.58
6	96:4 Al-Cu	0.188	1/63	1.57
7	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.185	1/64	1.54
8	90:8:2 Al-Cu-Mn	0.185	1/64	1.54
9	Duralumin	0.184	1/64	1.53
10	92:8 Al-Sn	0.184	1/64	1.53
11	96:4 Al-Mg	0.179	1/66	1.49
12	90:2:8 Al-Cu-Zn	0.179	1/66	1.49
13	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.177	1/67	1.48
14	97:3 Al-Si	0.175	1/67	1.46
15	90:8:2 Al-Cu-Ni	0.173	1/68	1.44
16	91:7:1:1 Al-Cu-Sn-Zn	0.173	1/68	1.44
17	92:8 Al-Cu	0.172	1/69	1.43
18	90:10 Al-Si	0.172	1/69	1.43
19	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.172	1/69	1.43
20	85:3:12 Al-Cu-Zn	0.171	1/69	1.43
21	90:8:2 Al-Cu-Zn	0.170	1/69	1.42
22	88:8:4 Al-Cu-Fe *a*	0.170	1/69	1.42
23	90:8:2 Al-Cu-Fe	0.170	1/69	1.42
24	90:8:2 Al-Cu-Sn	0.170	1/69	1.42
25	90:10 Al-Cu	0.168	1/70	1.40
26	88:12 Al-Cu	0.168	1/70	1.40
27	80:20 Al-Zn	0.167	1/71	1.39
28	85:14:1 Al-Cu-Ni	0.167	1/71	1.39
29	91.5:8:0.5 Al-Cu-Mg	0.166	1/71	1.38
30	77:3:20 Al-Cu-Zn	0.166	1/71	1.38
31	85:14:1 Al-Cu-Mn	0.165	1/72	1.38
32	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.164	1/72	1.37
33	85:5:10 Al-Cu-Sn	0.163	1/73	1.36
34	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.162	1/73	1.35
35	86:14 Al-Cu	0.160	1/74	1.33
36	88:4:8 Al-Cu-Sn	0.160	1/74	1.33
37	90:8:2 Al-Cu-Si	0.159	1/74	1.33
38	66:1:33 Al-Mn-Zn	0.156	1/76	1.30
39	67:33 Al-Zn	0.152	1/78	1.27
40	90:8:2 Al-Cu-Mg	0.149	1/80	1.24
41	92:8 Al-Mg	0.147	1/81	1.23
Least				

a Poured at 850° C.

TABLE 20.

Linear contraction of 41 light aluminum alloys, 0.5 by 1.0 inch bars poured at 700° C., in sand molds, arranged in the order of contraction.

Order of contraction	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
Greatest				
1	98:5:1.5 Al-Mn	0.202	1/59	1.68
2	97:2:1 Al-Cu-Mn	0.198	1/60	1.65
3	100 Al	0.197	1/60	1.64
4	92:8 Al-Ni	0.190	1/62	1.58
5	90:10 Al-Zn	0.185	1/64	1.54
6	Duralumin	0.184	1/64	1.53
7	95.5:3:1:0.5 Al-Cu-Fe-Mg	0.182	1/65	1.52
8	92:8 Al-Sn	0.180	1/66	1.50
9	90:2:8 Al-Cu-Zn	0.179	1/66	1.49
10	96:4 Al-Mg	0.179	1/66	1.49
11	95.5:1.5:1.5:1.5 Al-Cu-Mg-Ni	0.178	1/67	1.48
12	90:8:2 Al-Cu-Fe	0.178	1/67	1.48
13	96:4 Al-Cu	0.176	1/67	1.47
14	90:8:2 Al-Cu-Mn	0.173	1/68	1.44
15	97:3 Al-Si	0.172	1/69	1.43
16	85:14:1 Al-Cu-Ni	0.171	1/69	1.43
17	90:10 Al-Si	0.170	1/69	1.42
18	88:8:4 Al-Cu-Fe *a*	0.169	1/70	1.41
19	86.5:7:1:1.5:4 Al-Cu-Mn-Ni-Zn	0.169	1/70	1.41
20	91:7:1:1 Al-Cu-Sn-Zn	0.168	1/70	1.40
21	90:8:2 Al-Cu-Ni	0.168	1/70	1.40
22	90:10 Al-Cu	0.167	1/71	1.39
23	90:8:2 Al-Cu-Sn	0.165	1/72	1.38
24	80:20 Al-Zn	0.165	1/72	1.38
25	88:12 Al-Cu	0.164	1/72	1.37
26	92:8 Al-Cu	0.164	1/72	1.37
27	92.5:4:1.5:2 Al-Cu-Mg-Ni	0.164	1/72	1.37
28	76:3:0.5:0.5:20 Al-Cu-Mg-Mn-Zn	0.162	1/73	1.35
29	88:8:4 Al-Cu-Sn	0.162	1/73	1.35
30	85:14:1 Al-Cu-Mn	0.161	1/74	1.34
31	86:14 Al-Cu	0.160	1/74	1.33
32	90:8:2 Al-Cu-Zn	0.160	1/74	1.33
33	77:3:20 Al-Cu-Zn	0.160	1/74	1.33
34	85:3:12 Al-Cu-Zn	0.156	1/76	1.30
35	91.5:8:0.5 Al-Cu-Mg	0.156	1/76	1.30
36	66:1:33Al-Mn-Zn	0.155	1/77	1.29
37	85:5:10 Al-Cu-Sn	0.154	1/77	1.28
38	90:8:2 Al-Cu-Si	0.152	1/78	1.27
39	67:33 Al-Zn	0.152	1/78	1.27
40	90:8:2 Al-Cu-Mg	0.147	1/81	1.23
41	92:8 Al-Mg	0.146	1/81	1.22
Least				

a Poured at 850° C.

mental measurements on the contraction of the alloys in sand molds will be discussed at length in the following section.

E.—General Discussion of the Experiments, Effect of Various Factors on Contraction, and Conclusions

a.—General

The results of the experimental measurements show that the linear contraction of a series of 40 light aluminum alloys varies over a wide range, roughly from 0.95 to 1.80 per cent, depending upon a number of factors. These factors include the chemical composition of the alloys, the size of the section poured, the pouring temperature, the nature of the mold employed, and others. The effects of these factors have been indicated by the tabular data already given, and it is now of interest to discuss these factors and some others in detail as applied to the series of light aluminum alloys examined here in particular and to alloys in general. The factors which are of importance in affecting the contraction of an alloy on casting include the following:

(1) Chemical composition of the alloy.
(2) Pouring temperature.
(3) Cross section of the bar poured.
(4) Length of the bar in relation to its cross section.
(5) The character of the mold. and the method of molding.
(6) Gas occlusion, and overheating.

These factors, and others related to them, are discussed under a series of sub-heads in the following pages in the light of the available information and the present experiments.

b.—Effect of the Chemical Composition of the Alloy

Sufficient data are not available, on the basis of the present experimental figures, to warrant drawing definite conclusions as to the single and inter-related effects of various additive elements upon the contraction of aluminum and aluminum alloys over a wide range of composition. The mass of data collected in the experimental work has furnished values for the contraction of a series of alloys poured into bars under definite conditions, and the tendencies have been indicated fairly

clearly. In general, the effect of adding any element to aluminum is to decrease the contraction of aluminum, at least within limits, and the effects of copper, iron, magnesium, manganese, nickel, silicon, tin, and zinc in a restricted range have been indicated. In the case of further investigations on the contraction of aluminum alloys, the author would recommend the study of the contraction of the various binary alloy systems of aluminum which are of commercial interest, e. g., aluminum-copper, aluminum-iron, aluminum-magnesium, aluminum-manganese, aluminum-nickel, aluminum-silicon, aluminum-tin, aluminum-zinc, and some others. For some of these systems, it would be useful to examine the contraction of the alloys by intervals of 1.0 per cent throughout.

Of course, in considering the linear contraction of any alloy and its piping and contraction in volume on freezing, it is necessary to consider the diagram of thermal equilibrium for the particular alloy and to examine the phase changes that take place in the particular composition during freezing and cooling. It will serve no useful purpose here to discuss the theoretical aspects of freezing in relation to volume changes for all possible types of alloy systems, and it will be sufficient therefore to consider the freezing of two typical kinds of alloys; viz., an eutectiferous alloy, and a solid-solution alloy. The course of freezing can be examined readily by reference to the diagram of thermal equilibrium, and for the purpose of discussion two typical aluminum alloys may be examined; viz., (1) the 92:8 aluminum-copper alloy, representing an eutectiferous alloy, and (2) the 90:10 aluminum-zinc alloy, representing a solid-solution alloy.

1. *Freezing of An Eutectiferous Alloy:* 92:8 *Aluminum-Copper.* Fig. 4 shows part of the equilibrium diagram of the aluminum-copper system, after Merica, Waltenberg, and Freeman ([31]). The line *aa'* shows the position of the 92:8 aluminum-copper alloy in the system. This alloy begins to freeze at 636 degrees Cent., and freezing is complete at 540 degrees Cent., these temperatures being indicated by the points of intersection of the vertical line *aa'* with the liquidus and solidus respectively. The solidification range covers 96 degrees Cent.

The alloy begins to freeze when the temperature 636 degrees Cent. is reached, saturated crystals consisting of a solid solution of $CuAl_2$ in aluminum separating out as the excess substance, while the mother metal follows in composition the line from *a* to *e*. The first crystals to separate out have the

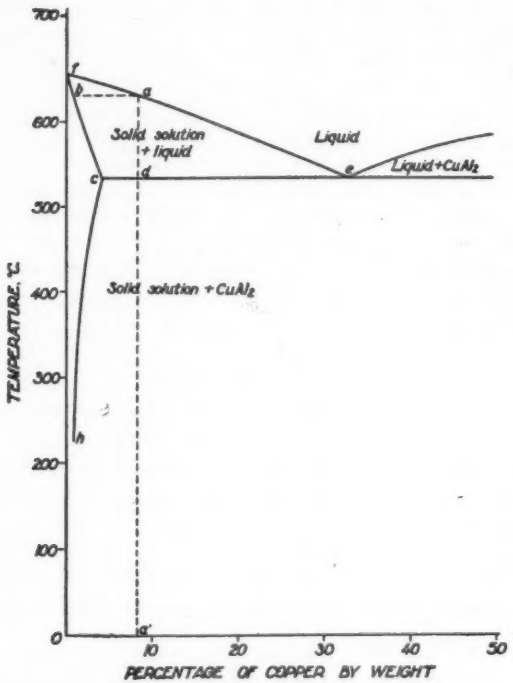

FIG. 4.—PARTIAL EQUILIBRIUM DIAGRAM OF THE ALUMINUM-COPPER SYSTEM (After Merica, Waltenberg and Freeman)

composition given by the intersection of the line *ab* through the point *a* with the solidus at *b*. The limit of the solubility of copper (as $CuA1_2$) in aluminum is 4.3 per cent, according to Merica and his collaborators ([31]), and crystals of the solid solution containing this amount of copper are in equilibrium

with the liquid of eutectic composition (32 per cent copper) at 540 degrees Cent.

The relative proportions of the liquid and solid then, as has been indicated by Edwards ([37]) in describing the freezing of the 92:8 aluminum-copper alloy, are *cd* and *de*. As the temperature drops during the course of freezing, i. e., when it falls to 540 degrees Cent., the liquid (mother metal) freezes as the eutectic, a conglomerate of the solid solution (solid solution of $CuAl_2$ in aluminum) and $CuAl_2$. The composition of the liquid and solid which is in equilibrium at any temperature in the range of freezing is given by the intersection of the horizontal temperature line in question with the liquidus and solidus, and the relative proportions of the liquid and solid substance are given by the inverse ratio in which the vertical line at 8 per cent copper (line *aa'*) divides the horizontal distance between the liquidus and solidus. Edwards ([37]) has calculated certain of these values from the diagram with the results given in Table 21.

TABLE 21.

Composition and proportions of solid and liquid in equilibrium in 92:8 aluminum-copper alloy at different temperatures.*

Temperature, degrees Cent.	Equilibrium composition		Proportions in equilibrium	
	Solid, per cent, copper	Liquid, per cent, copper	Solid, per cent	Liquid, per cent
636	0.9	8.0	0	100
616	1.6	14.4	50	50
600	2.2	19.0	66	34
560	3.6	28.0	82	18
540	4.3	32.0	86–100	14–0

* Based on Edwards.

When the temperature 540 degrees Cent. is reached in the course of cooling, about 86 per cent of the alloy has frozen and the remaining 14 per cent of liquid is of eutectic composition. This liquid then freezes at 540 degrees Cent. The foregoing refers to the equilibrium condition which can be obtained by an exceedingly slow rate of cooling, while under ordinary cooling rates equilibrium between the solid crys-

tals and the liquid will not be reached at any temperature. The result of this lack of equilibrium will be an increase in the amount of eutectic at 540 degrees Cent. From Table 21, it is apparent that the solid substance separates out most rapidly during the early part of the freezing, and the rate of separation decreases as the temperature falls. It has been indicated by Edwards that the first crystals which freeze out at 636 degrees Cent. have greater density than the mother metal, and they consequently tend to sink in the mass. At the same time, the crystals (of solid solution) which freeze out contain less copper than the liquid, and, further, copper is concentrating in the liquid during the drop of temperature in the freezing range; consequently, the liquid increases in density at a more rapid rate than the solid. The liquid and solid become equal in density at 630 degrees Cent., at which temperature about 25 per cent solid is present. At temperatures below 630 degrees Cent., the solid is of less density than the liquid. and it therefore tends to rise and float.

The consequence of this state of affairs is shown by the variation in copper content and density in different parts of cast ingots of the 92:8 aluminum-copper alloy. It is well known that in cast ingots of this alloy, the copper content increases from the top to the bottom, and the density increases likewise, and this segregation is well marked in the case of large, slowly-cooled ingots. However, when consideration is given to the difference in density between the crystals of the solid solution formed on freezing and the liquid, it will follow logically that segregation would be expected normally in this alloy and that the bottom of an ingot will be much richer in copper than the top.

The phase relations and changes existent in the freezing range have a bearing on the linear contraction of the alloy and upon the soundness. If a number of crystals of the solid are floating in the liquid, they tend to form a network which attains considerable rigidity near the end of the freezing range, i. e., at 540 degrees Cent. When the eutectic freezes, as it does last, there is a tendency for it to contract from the interstices of the network and consequently influence the amount

of total contraction. Apparently, the greater the amount of network the less effect will be exerted by the contraction of the eutectic, and consequently it would be expected that alloys higher in copper would have less contraction than those lower in copper. This has been proven by experimental measurements (cf. the linear contraction of the 92:8 and 86:14 aluminum-copper alloys). Moreover, the later contraction of the eutectic on freezing and the withdrawal of this alloy from the interstices of the network causes the presence of voids between the crystals, and this gives rise to porosity and unsoundness. Of course, in actual casting practice, the effect of the withdrawal of the eutectic is reduced substantially by feeding liquid alloy through gates and risers properly designed and placed.

2. *Freezing of a Solid-Solution Alloy*: 90:10 *Aluminum Zinc*. Fig. 5 shows part of the equilibrium diagram of the aluminum-zinc system after Hanson and Gayler ([47]). The line *aa'* shows the position of the 90:10 aluminum-zinc alloy in the system. The alloy begins to freeze at 638 degrees Cent., and freezing is complete at 565 degrees Cent., these temperatures being indicated by the points of intersection *a* and *b* of the vertical line *aa'* with the liquidus and solidus respectively. The solidification range covers 73 degrees Cent.

As indicated, the alloy begins to freeze when the temperature 638 degrees Cent. is reached, saturated crystals of a solid solution of zinc in aluminum (gamma crystals) separating out as the excess substance. It should be stated that for the composition given, the two metals are completely reciprocally soluble in the liquid and solid states, and when in equilibrium the 90:10 aluminum-zinc alloy in the solid state consists of the solid solution gamma—90:10 aluminum-zinc. However, there is a tendency to selective freezing in the alloy, and the result of this is to form continuously varying (within limits) solid solutions of the same type, those frozen first being richer in aluminum than those frozen last. The process of diffusion, however, tends to yield an alloy consisting of crystals of a solid solution of the same composition. Thus, the first crystals frozen out will solidify as a solid solution of the composition indicated by *c;* and, as the freezing continues, the composition of the frozen

crystals will travel along the curve *cb*, while the composition of the liquid (mother metal) will travel along the curve *ad*. Hence, if no diffusion were active, the last frozen crystals would

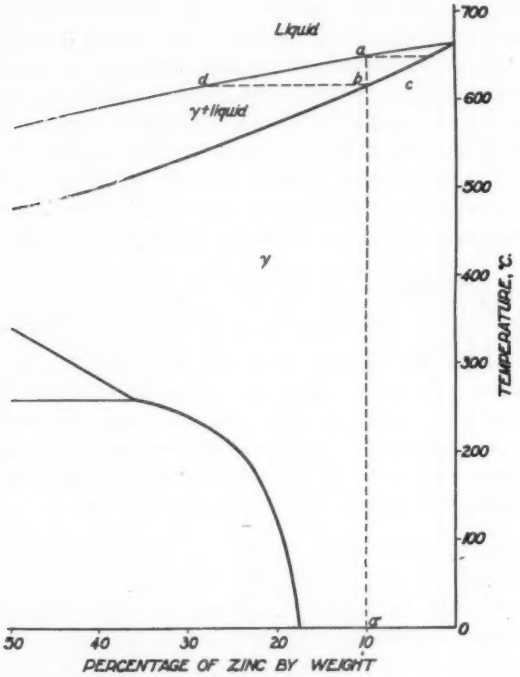

FIG. 5.—PARTIAL EQUILIBRIUM DIAGRAM OF THE ALUMINUM-ZINC SYSTEM (After Hanson and Gayler)

have the composition indicated by *d*, and the series of solid solutions making up the alloy would range in composition from *c* to *d*.

The condition of affairs indicated above affects the contraction and structure of alloys of the solid-solution type. Thus, in the case of the 90:10 aluminum-zinc alloy, during the course of freezing, indicated by the temperature interval *ab*, there is present liquid and solid phases of different densities existing

simultaneously, and the net result is comparable to that discussed above under the freezing of the 92:8 aluminum-copper alloy. As regards the microstructure, the selective freezing of solid-solution alloys gives rise to bad coring and segregation with simultaneous injury to the possible properties of the alloy.

It will be evident that there may be possible expansions of phases during the course of freezing, i. e., in the freezing interval, and that these will affect the pattern allowance to be made in actual casting practice. The demonstration of the reality of the increase of volume or rather length of alloys on freezing has been made by Turner and his students, and determinations of this character are of value in foundry practice.

It should be added here that the extent to which piping occurs on casting an alloy in an open-top ingot mold is a factor in determining the suitability of an alloy for casting purposes since the apparent piping is an indication of the contraction in volume. Numerous experiments carried out in the bureau of mines have shown that the depth of pipe varies greatly among light aluminum alloys, depending upon their chemical composition, and that the amount of piping is a determining factor in selecting alloys for casting purposes.

3. *Effect of the Chemical Composition of Some Light Aluminum Alloys on Their Contraction.* Turning now to a consideration of the effect of the chemical composition of some alloys upon their contraction in chill molds and in sand molds, for convenience in discussion the alloys have been segregated into groups as shown in the accompanying tables, and the effects of different additive elements upon the contraction of aluminum and certain of its alloys are taken up in the following paragraphs:

I.—Contraction in Chill Molds

(a)—*Effect of Copper*:—Copper in increasing amounts up to 12 per cent lowers the contraction of aluminum from 1.68 per cent to 1.19 per cent, and Table 22 shows the effect of increasing copper on the contraction for the pouring-temperature range 700 to 800 degrees Cent.

TABLE 22.

Linear contraction of binary aluminum-copper alloys; mean contraction when poured at 700 to 800 degrees C. in graphite molds.

Alloy number	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
1	100 Al.....	0.198	1/60	1.65
2	96:4 Al-Cu.....	0.163	1/73	1.36
3	92:8 Al-Cu.....	0.161	1/74	1.34
4	90:10 Al-Cu.....	0.149	1/80	1.24
5	88:12 Al-Cu.....	0.143	1/83	1.19
6	86:14 Al-Cu.....	0.144	1/82	1.20

(b)—*Effect of Iron*:—Iron decreases the contraction of aluminum and of aluminum-copper alloys, and in foundry practice cracking in the molds on casting the ordinary 92:8 aluminum-copper alloy can often be overcome by increasing the iron to 1.0 to 1.5 per cent. Iron to the amount of 4 per cent when added to the 92:8 aluminum-copper alloy causes the alloy to become viscous and increases the melting point, and renders the alloy difficult to cast. Table 23 shows the effect of increasing iron on the contraction of the 92:8 aluminum-copper alloy, for the pouring-temperature range 700 to 800 degrees Cent.

TABLE 23.

Linear contraction of aluminum-copper-iron alloys; mean contraction when poured at 700 to 800 degrees Cent. in graphite molds.

Alloy number	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
3	92:8 Al-Cu.....	0.161	1/74	1.34
17	90:8:2 Al-Cu-Fe.....	0.155	1/77	1.29
18	88:8:4 Al-Cu-Fe*.....	0.145	1/82	1.21

* In the pouring-temperature range 900 to 950 degrees Cent.

(c)—*Effect of Magnesium*:—Magnesium has a pronounced effect in lessening the contraction of aluminum and its alloys, as may be seen from the figures in Table 24. Thus, the addition of 8 per cent magnesium lowers the contraction of aluminum

TABLE 24.

Linear contraction of magnesium-containing aluminum alloys; mean contraction when poured at 700 to 800 degrees Cent. in graphite molds.

Alloy number	Nominal composition	Linear contraction		
		Inch per foot	Pattern-maker's scale	Per cent
1	100 Al	0.198	1/60	1.65
7	96:4 Al-Mg	0.166	1/71	1.38
8	92:8 Al-Mg	0.138	1/86	1.15
3	92:8 Al-Cu	0.161	1/74	1.34
19	91.5:8:0.5 Al-Cu-Mg	0.152	1/78	1.27
20	90:8:2 Al-Cu-Mg	0.130	1/92	1.08

from 1.65 to 1.15 per cent, and the effect of magnesium is more pronounced than that of copper. Magnesium markedly lowers the contraction of aluminum-copper alloys, and its effect is much stronger than that of iron. Cracking in the 92:8 aluminum-copper alloy may be overcome often by the addition of 0.5 per cent magnesium.

(d)—*Effect of Manganese*:—Manganese has a pronounced effect to increase the contraction of light aluminum alloys. An addition of 1.5 per cent manganese to aluminum decreases the contraction only slightly, while manganese when added to aluminum-copper and aluminum-zinc alloys increases the contraction markedly. Table 25 gives some comparative figures.

(e)—*Effect of Nickel*:—The effect of nickel on the con-

TABLE 25.

Lienar contraction of manganese-containing aluminum alloys; mean contraction when poured at 700 to 800 degrees Cent. in graphite molds.

Alloy number	Nominal composition	Linear contraction		
		Inch per foot	Pattern-maker's scale	Per cent
1	100 Al	0.198	1/60	1.65
9	98.5:1.5 Al-Mn	0.193	1/61	1.61
3	92:8 Al-Cu	0.161	1/74	1.34
22	90:8:2 Al-Cu-Mn	0.168	1/70	1.40
6	86:14 Al-Cu	0.144	1/82	1.20
23	85:14:1 Al-Cu-Mn	0.151	1/78	1.26
16	67:33 Al-Zn	0.114	1/104	0.95
34	66:1:33 Al-Mn-Zn	0.133	1/89	1.11

traction of aluminum is not so marked as that of copper, and its effects upon aluminum-copper alloys are variable, apparently, depending upon the composition. Table 26 gives some comparative figures.

TABLE 26.

Linear contraction of some nickel-containing aluminum alloys; mean contraction when poured at 700 to 800 degrees Cent. in graphite molds.

Alloy number	Nominal composition	Linear contraction		
		Inch per foot	Pattern-maker's scale	Per cent
1	100 Al	0.198	1/60	1.65
10	92:8 Al-Ni	0.170	1/69	1.42
3	92:8 Al-Cu	0.161	1/74	1.34
24	90:8:2 Al-Cu-Ni	0.150	1/79	1.25
6	86:14 Al-Cu	0.144	1/82	1.20
25	85:14:1 Al-Cu-Ni	0.149	1/80	1.24

(f)—*Effect of Silicon*:—Silicon has remarkable effects in decreasing the contraction of aluminum and its alloys. When added to aluminum, 3 per cent silicon reduces the contraction from 1.65 per cent to 1.28 per cent, and 10 per cent silicon reduces it to 1.11 per cent. Some comparative figures are given in Table 27.

TABLE 27.

Linear contraction of some silicon-containing aluminum alloys; mean contraction when poured at 700 to 800 degrees Cent. in graphite molds.

Alloy number	Nominal composition	Linear contraction		
		Inch per foot	Pattern-maker's scale	Per cent
1	100 Al	0.198	1/60	1.65
11	93:7 Al-Si	0.154	1/77	1.28
12	90:10 Al-Si	0.133	1/89	1.11
6	92:8 Al-Cu	0.161	1/74	1.34
26	90:8:2 Al-Cu-Si	0.140	1/84	1.17

(g)—*Effect of Tin*:—Tin reduces the contraction of aluminum, but its effect is not quite so pronounced as that of copper. Tin reduces also the contraction of aluminum-copper alloys. Some comparative figures are given in Table 28.

TABLE 28.

Linear contraction of some tin-containing aluminum alloys; mean contraction when poured at 700 to 800 degrees Cent. in graphite molds.

Alloy number	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
1	100 Al	0.198	1/60	1.65
13	92:8 Al-Sn	0.166	1/71	1.38
3	92:8 Al-Cu	0.161	1/74	1.34
27	90:8:2 Al-Cu-Sn	0.151	1/78	1.26
28	88:8:4 Al-Cu-Sn	0.149	1/80	1.24
29	85:5:10 Al-Cu-Sn	0.149	1/80	1.24

(h)—*Effect of Zinc*:—Zinc reduces the contraction of aluminum, but its effect is not quite so pronounced as that of copper. However, since alloys containing up to 33 per cent zinc are suitable for some castings, commercial aluminum-zinc alloys may be employed which have less contraction than commercial aluminum-copper alloys containing up to 14 per cent copper. Table 29 gives some comparative figures for the contraction of zinc-containing aluminum alloys.

TABLE 29.

Linear contraction of some zinc-containing aluminum alloys; mean contraction when poured at 700 to 800 degrees Cent. in graphite molds.

Alloy number	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
1	100 Al	0.198	1/60	1.65
14	90:10 Al-Zn	0.164	1/72	1.37
15	80:20 Al-Zn	0.145	1/82	1.21
16	67:33 Al-Zn	0.114	1/104	0.95
3	92:8 Al-Cu	0.161	1/74	1.35
30	90:2:8 Al-Cu-Zn	0.168	1/70	1.40
31	90:8:2 Al-Cu-Zn	0.155	1/77	1.29
32	85:3:12 Al-Cu-Zn	0.151	1/78	1.26
33	77:3:20 Al-Cu-Zn	0.139	1/85	1.16

(i)—*Effect of Additions of 2 Per Cent of Various Metals on the Contraction of 92:8 Aluminum-Copper Alloy*:—Table 30 shows the comparative linear contraction of four alloys of the 92:8 A1-X type, and Table 31 gives data for the comparative contraction of a number of alloys of the 90:8:2 Al-Cu-X type,

TABLE 30.

Comparative linear contraction of various binary alloys of the 92:8 Al-X type; mean contraction when poured at 700 to 800 degrees Cent in graphite molds.

Alloy number	Nominal composition	Linear contraction: Inch per root	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
3	92:8 Al-Cu.....	0.161	1/74	1.34
8	92:8 Al-Mg.....	0.138	1/86	1.15
10	92:8 Al-Ni.....	0.170	1/69	1.42
13	92:8 Al-Sn.....	0.166	1/71	1.38

when poured in chill molds, which may be found useful for ready reference. When added to aluminum in the amount of 8 per cent, the metals are to be listed as follows in the order of their effect upon the contraction; (1) magnesium; (2) copper;

TABLE 31.

Comparative linear contraction of various ternary alloys of the 90:8:2 Al-Cu-X type; mean contraction when poured at 700 to 800 degrees C. in graphite molds.

Alloy number	Nominal composition	Linear contraction: Inch per foot	Linear contraction: Pattern-maker's scale	Linear contraction: Per cent
3	92:8 Al-Cu.....	0.161	1/74	1.34
17	90:8:2 Al-Cu-Fe.....	0.155	1/77	1.29
20	90:8:2 Al-Cu-Mg.....	0.130	1/92	1.08
22	90:8:2 Al-Cu-Mn.....	0.168	1/70	1.40
24	90:8:2 Al-Cu-Ni.....	0.150	1/79	1.25
26	90:8:2 Al-Cu-Si.....	0.140	1/84	1.17
27	90:8:2 Al-Cu-Sn.....	0.151	1/78	1.26
31	90:8:2 Al-Cu-Zn.....	0.155	1/77	1.29

(3) tin, and (4) nickel, where the first mentioned has the greatest effect in lowering the contraction. Similarly, when 2 per cent of different metals is added as a substitute for aluminum in the 92:8 aluminum-copper alloy, giving rise to ternary alloys of the 90:8:2 A1-Cu-X type, the metals are to be listed as follows in the order of their effect upon the contraction; (1) magnesium, (2) silicon, (3) nickel, (4) tin, (5) zinc, (6) iron, and (7) manganese, where the first mentioned has the greatest effect in lowering the contraction.

II.—Contraction in Sand Molds

(a)—*Effect of Copper*:—Table 32 shows the effect of increasing copper on the contraction of aluminum in amounts of up

TABLE 32.

Linear contraction of binary aluminum-copper alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal compositon	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
1	100 Al.....	1.68	1.68	1.64	1.54	1.60
2	96:4 Al-Cu.....	1.43	1.57	1.47	1.43	1.48
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
4	90:10 Al-Cu.....	1.40	1.40	1.39	1.28	1.37
5	88:12 Al-Cu.....	1.35	1.40	1.37	1.25	1.27
6	86:14 Al-Cu.....	1.30	1.33	1.33	1.28	1.32

to 14 per cent, in the case of three different bars poured at 700 degrees Cent. and of two bars poured at 900 degrees Cent. In the case of the 0.5-inch square bars poured at 700 degrees Cent., the contraction falls from 1.65 per cent to 1.30 per cent on increasing the copper up to 14 per cent, and there is a corresponding drop in the case of the other bars. In the case of the bars poured at 900 degrees Cent., the contraction falls with increasing copper up to 12 per cent, and then rises with further increase to 14 per cent.

(b)—*Effect of Iron*:—It is shown by the measurements that increasing iron has practically no effect on the contraction of aluminum-copper alloys when cast in sand molds at 700 degrees Cent., as contrasted with casting in chill molds where increasing iron decreases the contraction. This is one of the marked anomalies between the values for alloys cast in different types of molds. Some comparative figures are given in Table 33.

(c)—*Effect of Magnesium*:—Magnesium has a pronounced effect in lowering the contraction of aluminum and aluminum-copper alloys as may be noted from the figures of Table 34. Thus, the addition of 8 per cent magnesium to aluminum lowers the contraction from 1.68 to 1.23 per cent in the case of 0.5-inch square bars poured at 700 degrees Cent. The addition of 0.5 per cent magnesium to the 92:8 aluminum-copper

TABLE 33.

Linear contraction of aluminum-copper-iron alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
17	90:8:2 Al-Cu-Fe....	1.43	1.42	1.48	1.45	1.43
18	88:8:4 Al-Cu-Fe....	1.40*	1.42*	1.41*	1.32**	1.40**

* Poured at 850 degrees Cent.
** Poured at 950 degrees Cent.

alloy lowers the contraction from 1.42 to 1.30 per cent, under the same experimental conditions.

(d)—*Effect of Manganese*:—Manganese has a pronounced effect in increasing the contraction of aluminum-copper and

TABLE 34.

Linear contraction of some magnesium-containing aluminum alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
1	100 Al.....	1.68	1.68	1.64	1.54	1.60
7	96:4 Al-Mg.....	1.47	1.49	1.49	1.50	1.50
8	92:8 Al-Mg.....	1.23	1.23	1.22	1.24	1.27
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
19	91.5:8:0.5 Al-Cu-Mg	1.30	1.38	1.30	1.23	1.39
20	90:8:2 Al-Cu-Mg...	1.22	1.24	1.23	1.16	1.23

aluminum-zinc alloys, and in small amounts it increases the contraction of aluminum, as may be seen by the comparative figures given in Table 35.

(e)—*Effect of Nickel*:—The effect of nickel on the contraction of aluminum is not nearly so marked as that of copper, and its effects upon light aluminum alloys are variable

TABLE 35.

Linear contraction of some manganese-containing aluminum alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
1	100 Al.....	1.68	1.68	1.64	1.54	1.60
9	98.5:1.5 Al-Mn.....	1.68	1.75	1.68	1.68	1.80
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
22	90:8:2 Al-Cu-Mn...	1.48	1.54	1.44	1.42	1.48
6	86:14 Al-Cu.....	1.30	1.33	1.33	1.28	1.32
23	85:14:1 Al-Cu-Mn..	1.36	1.38	1.34	1.30	1.38
16	67:33 Al-Zn.....	1.28	1.27	1.27	1.25	1.27
34	66:1:33 Al-Mn-Zn..	1.29	1.30	1.29	1.28	1.25

depending upon the composition. Some comparative figures are given in Table 36.

TABLE 36.

Linear contraction of some nickel-containing aluminum alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
1	100 Al.....	1.68	1.68	1.64	1.54	1.60
10	92:8 Al-Ni.....	1.61	1.60	1.58	1.54	1.60
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
24	90:8:2 Al-Cu-Ni....	1.40	1.44	1.40	1.35	1.38
6	86:14 Al-Cu.....	1.30	1.33	1.33	1.28	1.32
25	85:14:1 Al-Cu-Ni...	1.41	1.39	1.43	1.38	1.39

(f)—*Effect of Silicon*:—The figures given in Table 37 show that the effect of silicon alone on the contraction of aluminum is of the order of that of copper, but it reduces appreciably the contraction of the 92:8 aluminum-copper alloy when added in the amount of 2 per cent. The effect of silicon on the contraction of aluminum and aluminum-copper alloys is much greater in the case of bars poured in chill molds than in sand molds, and the values reported here for the contraction in sand

TABLE 37.

Linear contraction of some silicon-containing aluminum alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
1	100 Al.....	1.68	1.68	1.64	1.54	1.60
11	97:3 Al-Si.....	1.45	1.46	1.43	1.34	1.38
12	90:10 Al-Si.....	1.43	1.43	1.42	1.28	1.35
6	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
26	90:8:2 Al-Cu-Si....	1.24	1.33	1.27	1.19	1.23

molds are substantially higher than those reported by some observers. It is possible that the remelting of the silicon-containing alloys had some effect upon the contraction and that heating to high temperatures altered the properties of the alloys.

(g)—*Effect of Tin*:—Tin reduces the contraction of aluminum, and aluminum-copper alloys; its effect on aluminum, however, is not so marked as that of copper. Some comparative figures are given in Table 38.

TABLE 38.

Linear contraction of some tin-containing aluminum alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
1	100 Al.....	1.68	1.68	1.64	1.54	1.60
13	92:8 Al-Sn.....	1.49	1.53	1.50	1.31	1.48
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
27	90:8:2 Al-Cu-Sn....	1.39	1.42	1.38	1.25	1.38
28	88:8:4 Al-Cu-Sn....	1.31	1.33	1.35	1.25	1.35
29	85:5:10 Al-Cu-Sn...	1.30	1.36	1.28	1.27	1.32

(h)—*Effect of Zinc*:—Zinc lowers the contraction of aluminum, but its effect is not so pronounced as that of copper. However, as has been indicated previously, some alloys containing up to 33 per cent zinc are suitable for certain castings,

and commercial aluminum-zinc alloys may be employed that have less contraction than commercial aluminum-copper alloys containing up to 14 per cent copper. Table 39 gives some comparative figures for the linear contraction of zinc-containing aluminum alloys.

TABLE 39.

Linear contraction of some zinc-containing aluminum alloys; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
1	100 Al.....	1.68	1.68	1.64	1.54	1.60
14	90:10 Al-Zn.....	1.53	1.58	1.54	1.44	1.55
15	80:20 Al-Zn.....	1.42	1.39	1.38	1.33	1.43
16	67:33 Al-Zn.....	1.28	1.27	1.27	1.25	1.27
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
30	90:2:8 Al-Cu-Zn....	1.49	1.42	1.49	1.42	1.43
31	90:8:2 Al-Cu-Zn....	1.37	1.43	1.33	1.25	1.46
32	85:3:12 Al-Cu-Zn...	1.34	1.38	1.30	1.38	1.35
33	77:3:20 Al-Cu-Zn...	1.35	1.30	1.33	1.33	1.25

(i)—*Effect of Additions of* 2 *Per Cent of Various Metals on the Contraction of* 92:8 *Aluminum-Copper Alloy*:—Table 40 shows the comparative linear contraction of four alloys of the

TABLE 40.

Comparative linear contraction of some binary alloys of the 92:8 Al-X type; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
8	92:8 Al-Mg.....	1.23	1.23	1.22	1.24	1.27
10	92:8 Al-Ni.....	1.61	1.60	1.58	1.54	1.60
13	92:8 Al-Sn.....	1.49	1.53	1.50	1.31	1.48

92:8 A1-X type, and Table 41 gives data for the comparative contraction on a number of alloys of the 90:8:2 A1-Cu-X type,

TABLE 41.

Comparative linear contraction of various ternary alloys of the 90:8:2 Al-Cu X type; bars of different cross sections poured at high and low temperatures in sand molds.

Alloy number	Nominal composition	Linear contraction, per cent, for bars poured at 700 degrees Cent.			Linear contraction, per cent, for bars poured at 900 degrees Cent.	
		0.5-inch square bars	1.0-inch square bars	0.5 by 1.0 inch bars	0.5-inch square bars	1.0-inch square bars
3	92:8 Al-Cu.....	1.42	1.43	1.37	1.33	1.40
17	90:8:2 Al-Cu-Fe....	1.43	1.42	1.48	1.45	1.43
20	90:8:2 Al-Cu-Mg...	1.22	1.24	1.23	1.16	1.23
22	90:8:2 Al-Cu-Mn...	1.48	1.54	1.44	1.42	1.48
24	90:8:2 Al-Cu-Ni....	1.40	1.44	1.40	1.35	1.38
26	90:8:2 Al-Cu-Si....	1.24	1.33	1.27	1.19	1.23
27	90:8:2 Al-Cu-Sn....	1.39	1.42	1.38	1.25	1.38
31	90:8:2 Al-Cu-Zn....	1.37	1.42	1.33	1.25	1.46

which may be found useful for ready reference. When added to aluminum in the amount of 8 per cent, the metals are to be listed as follows in the order of their effect upon the contraction; (1) magnesium, (2) copper, (3) tin, and (4) nickel, where the first mentioned has the greatest effect in lowering the contraction. This refers to 0.5-inch square bars poured at 700 degrees Cent. Similarly, where 2 per cent of different metals is added as a substitute for aluminum in the 92:8 aluminum-copper alloy, giving rise to ternary alloys of the 90:8:2 Al-Cu-X type, the metals are to be listed as follows in the order of their effect upon the contraction; (1) magnesium, (2) silicon, (3) zinc, (4) tin, (5) nickel, (6) iron, and (7) manganese, where the first mentioned has the greatest effect in lowering the contraction and the last mentioned actually increases the contraction. This refers also to 0.5-inch square bars poured at 700 degrees Cent.

In the case of both chill-cast and sand-cast bars, definite conclusions, as to the effect of additive elements on the contraction of aluminum and its light alloys over a wide range of composition, cannot be drawn, on the basis of the present tests, because of inadequacy of the data, but the results are indicative of what effects are secured in a limited range of composition embraced by the commercial alloys.

c.—Effect of the Pouring Temperature

The linear contraction of a metal or alloy on pouring into a mold is a function of the pouring temperature—the higher the pouring temperature, the greater the contraction, since less metal can be put into a cavity of a given size at a higher temperature than at a lower one. The effect of the pouring temperature upon the contraction of a series of light aluminum alloys has been indicated by the experiments described in this paper. Theoretically, the higher pouring temperature, the greater the contraction, because of the decrease in density of the alloys in the liquid state with increasing temperature, but actually an intermediate pouring temperature normally yields a greater contraction than a high or low pouring temperature.

The reason for this condition of affairs is not hard to find, and the fact that a less contraction is given by pouring at a higher pouring temperature than at an intermediate one is traceable to the dissolution of gas. As is well known, metals and alloys dissolve more gas with increasing temperatures, and when this gas is given off on freezing it causes expansion and, therefore, interferes with the normal contraction of the alloy.

Turning back to a consideration of the theoretical effect of the pouring temperature upon contraction, irrespective of the effect of dissolved gas, it will be recalled that the contraction in volume of an alloy on passing from the liquid state at any temperature to the solid state, say at room temperature, is the algebraic sum of the liquid shrinkage plus the solidification shrinkage plus the solid shrinkage. This fact does not seem to be recognized altogether clearly by some foundrymen and metallurgists, as is indicated by Dix in his discussion of the author's paper ([49]) on cracks in aluminum-alloy castings. Dix draws attention to his useful method for determining the cracking tendency in alloys by pouring a bar with enlarged ends to fit around two steel pins rigidly held 12 inches apart. After the alloy is poured, in this method, the cope is lifted off and the sand scraped away. It is stated that the test bar is always solid and gives no indication of a crack until several minutes later, the time varying with the alloy under test. It is obvious, according to Dix, that in this case the liquid shrinkage can

have no effect on the cracking tendency because liquid alloy is fed into the mold by two risers. It is claimed also that the solidification shrinkage does not have much effect in this particular case, so that the solid contraction is practically the sole cause of the cracking. In actual castings, it is not always possible to feed the casting with liquid metal as well as in this case, therefore, the solidification shrinkage may have more effect, but it is hard to believe that the liquid shrinkage enters the problem at all.

The reasoning applied by Dix is correct so far as it goes when applied to the particular case under discussion by him but it is not at all valid as applied to the theoretical consideration of contraction. The fact that castings cannot be always, or are not, fed properly is shown by large internal draws and pipes which occur, indicating also incorrect pattern allowances.

Referring to the measurements made on the contraction of the aluminum alloys in chill molds, it was shown from the mass of data that pouring at some intermediate temperature in the range 650 to 1,000 degrees Cent. gives greater contraction than pouring at a lower temperature or at a higher temperature. It was pointed out that the average difference in the contraction of the series of alloys between the highest and lowest values is 0.095 per cent, thus establishing the fact that the pouring temperature affects the contraction under the conditions of experiment. As regards the sand-cast bars, it has been shown definitely by the experimental measurements that, for most of the alloys, pouring at 900 degrees Cent. gives substantially less contraction than pouring at 700 degrees Cent. This refers to both 0.5 and 1.0-inch square bars. Taking up first the comparison of the 0.5-inch square bars poured, in the different alloys, at 700 and 900 degrees Cent.: Of the 41 alloys, 33 had less contraction when poured at 900 than at 700 degrees Cent., four had the same contraction (i.e., the pouring temperature apparently had no effect upon the contraction and four had greater contraction. The average excess of per cent linear contraction for the bars poured at 700 over those poured at 900 degrees Cent. was 0.059 per cent. In the case of the 1.0-inch square bars: Of the 41 alloys, 23 had less contraction when

poured at 900 than at 700 degrees Cent., five had the same contraction, and 13 had greater contraction. The average excess of per cent linear contraction for the 1.0-inch square bars poured at 700 over those poured at 900 degrees Cent. was 0.021 per cent. There is, therefore, wider variation in contraction with the pouring temperature in the case of the smaller bars. The fact that most of the alloys had less contraction on pouring at 900 than at 700 degrees Cent. is explained most likely by the effect of gas occlusion, the evolution of gas on freezing causing expansion which interferes with the normal contraction of the alloys. The fact that some of the alloys had greater contraction on pouring at the high temperature than at the low temperature would be expected from theoretical considerations, and in these cases the effect of gas occlusion was apparently not active.

The pouring temperature effects also the presence of blowholes ([32]), and these in turn affect the contraction. The pouring temperature also influences the rate of cooling; a high pouring temperature will cause a slower rate of cooling than a low pouring temperature, and a rapid rate of freezing yields greater contraction than a slower rate. This is also in accordance with the fact that a high pouring temperature yields a greater contraction than a low pouring temperature. It is shown also by the experiments that in most light aluminum alloys poured at a high temperature, bars are rough as to surface owing to gas evolution.

d.—Effect of the Cross Section of the Bar Poured

In casting practice, it is well known that the contraction depends upon the cross section of the casting, and it has been shown in the present tests (cf. tabular matter as to values on pouring bars of different cross sections in sand molds) that the total linear contraction is a function of the cross-sectional area of the bar. Given all other conditions the same, the smaller the cross-sectional area of the bar the less the contraction, 0.5-inch square bars having less contraction than 1.0-inch square bars for a given length. In casting practice, it has been observed, of course, that thin sections contract less than thick sections, and the cracking of a casting at the juncture of a thin

and thick section is attributed to the contraction of the thick section continuing after the thin section has frozen.

In a casting, the contraction allowance is dependent upon the mass of the casting, its design, and the relation between the thick and thin sections, so that for the same alloy, different pattern allowances are made for thick and thin castings. The contour of the pattern is of importance also, but it is not possible, with the available data, to set down any rules to be applied.

It has been shown definitely by the mass of data obtained in the present investigation that small bars give less contraction than large bars, and evidently the contraction is a direct function of the cross-sectional area of bar for a given length, all other factors being kept constant. As would be expected, the least contraction of the various alloys was observed by pouring 0.5-inch square bars at 900 degrees Cent., while the greatest was given by the 1.0-inch square bars poured at 700 degrees Cent. In other words, the smaller the size of section and the higher the pouring temperature the less the contraction, and the greater the size of section and the lower the pouring temperature the greater the contraction.

e.—Effect of the Length of the Bar Poured

When an alloy is cast in the form of a cube, the alloy contracts uniformly in all directions, but in a bar the contraction takes place chiefly in the direction of the length, and the thinner the bar, the greater is the disproportion between the contraction in the different directions. According to Turner ([30]), this holds for cast iron, and copper and its alloys behave in an exactly opposite manner. Comparative data as to the linear contraction of bars, of aluminum alloys cast under identical conditions, of the same cross section but different lengths are not available, but with greater length for a given size cross section, it is indicated that the contraction is less. The relations between the inter-related effects of the cross section and length of a bar upon the contraction have not been worked out systematically, but the general tendencies are known.

f.—Effect of the Character of the Mold, and the Method of Molding

The linear contraction of the light alloys when poured into the chill molds was less than when poured into the sand molds, but the figures are not comparative because bars of different lengths were employed. Theoretically, it would be expected that a bar cast in a chill mold would have greater contraction than one poured in a sand mold, in the case of alloys with a time interval of freezing. A mold of high thermal conductivity will dissipate heat more rapidly than one of lower thermal conductivity, and the rate of freezing will be faster in the first type of mold. Freezing is, therefore, faster in a chill mold than in a sand mold, and the contraction allowances in die casting are necessarily different than in sand casting. It has been shown by Turner that when there is a freezing interval (i.e., where there is a temperature range between the liquidus and the solidus) in an alloy, sand-cast bars have lower density than chill-cast bars. Thus, slower cooling gives less density than rapid cooling, which would indicate greater contraction for chill-cast bars than sand-cast ones. This does not accord strictly with the experimental results obtained in the present investigation, but these results are not strictly comparable.

In sand-casting practice, the contraction allowance to be made is influenced necessarily by the method of molding, i.e., as to the number, size, and position of gates and risers. The normal free contraction of an alloy in the form of a casting may be hindered by too many risers which cause hanging of the casting in the mold and give rise to shrinkage cracks in some cases. Too hard ramming may interfere also with the contraction, and too much moisture in the sand may cause blows as well as affect the contraction. The function of a riser is to feed liquid metal to a contracting portion of a casting, thereby preventing porosity and draws, so that the normal shrinkage of a casting is affected by the size and number of risers attached. Where a casting is thoroughly fed up with risers, the effect of the liquid shrinkage is minimized in certain portions of the casting, but in other portions the full

contraction in volume (being the sum of the liquid shrinkage plus the solidification shrinkage plus the solid shrinkage) obtains on pouring the casting.

The more detailed practical character of the effect of the method of molding on the contraction of castings need not be dealt with here but the principles indicated will be found of value in the design of patterns and in actual casting practice. It is difficult to make experiments, which will be of value in a practical way, to show the influence of molding methods on contraction, but a few experiments were carried out, in connection with the present investigation, designed to give indications of the tendencies. Experiments were made with 92:8 aluminum-copper alloy, cast in sand molds, in which the size of the pouring gate and lead-off runner were varied; the data are summarized in Table 42. It is shown by the figures that when a 2-inch diameter pouring gate was substituted for

TABLE 42.

Linear contraction of 92:8 aluminum-copper alloy, poured at high and low temperatures in sand molds, as influenced by the molding conditions.

Pouring temperature, deg. Cent.	Cross section of bar, inch	Linear contraction, per cent: Ordinary molding conditions; pouring gate 1¼ inches diameter; runner one-half the thickness of the bar	Ordinary molding conditions; pouring gate 1¼ inches diameter; runner one-half the thickness of the bar	Ordinary molding conditions; but pouring gate 2 inches diameter; runner one-half the thickness of the bar	Ordinary molding conditions; pouring gate 1¼ inches in diameter; but runner same thickness as the bar
700	0.5 x 0.5	1.42	1.35	1.44	1.38
700	1.0 x 1.0	1.43	1.46	1.45	1.43
700	0.5 x 1.0	1.37	1.40	1.40	1.27
900	0.5 x 0.5	1.33	1.39	1.31	1.23
900	1.0 x 1.0	1.40	1.43	1.47	1.42

the usual gate 1¼ inches in diameter, thus giving a greater feeding effect, the contraction was increased for all the bars except the 0.5-inch square size poured at 900 degrees Cent. The effect of increasing the size of the lead-off runner apparently was to decrease the contraction. The reasons for these results are not clear, and further experiments are necessary before final conclusions can be drawn.

g.—Gas Occlusion, and Overheating

Desch ([20]) and others find that an overheated melt contains more gas at the moment of pouring than a melt which has been heated merely to the correct pouring temperature, and apparently overheated melts readily remain supersaturated with gas. As is well known, metals and alloys do not obey Henry's law, but the higher a metal is heated in the liquid state the more gas it dissolves. The effect of gas occlusion owing to high melting and pouring temperatures upon the contraction of alloys is to lessen the normal contraction because of the evolution of gas on freezing which causes actual expansion and therefore interferes with the normal free contraction. If no gas were dissolved, the higher the pouring temperature, the greater would be the contraction.

While pouring at a low temperature after cooling from a high temperature minimizes the deleterious effects of overheating, an overheated melt will give rise to blowholes and porosity because of the evolution of gas on freezing. This condition of affairs markedly affects the contraction, and in pattern practice allowance should be made for the temperature at which the castings must be poured. This refinement of practice is not necessarily expensive and by no means uneconomical when considered in relation to the wasters which normally occur in founding owing to poor pattern practice, incorrect methods of molding, and bad melting and pouring procedure.

h.—Casting Properties of the Alloys

From the point of view of founding it is of great importance to select alloys which possess good casting properties, and it is of interest here to mention briefly some of the factors which determine the casting properties of any alloy. Turner ([41]) has discussed a number of factors which affect the casting properties of alloys, and among other items the question of contraction and shrinkage is given a prominent place. To sum up, the greatest cause for difficulty in the founding of the light aluminum alloys is their high contraction, but as has been shown in the present paper the contraction of the useful alloys varies over a wide range, and the contraction of any given alloy may be lowered by the addition of certain metals.

In development work on light aluminum alloys hitherto, it appears that efforts have been extended largely in the direction of obtaining high physical and mechanical properties irrespective of the casting properties, leaving the problem of making the castings entirely to the molder. This method of procedure cannot yield the best results, since, in the final analysis, alloys are desired which primarily shall be susceptible to easy casting in the foundry, and the question of mechanical properties is really secondary. A case in point may be cited n the development of the 92.5:4:1:2 Al-Cu-Mg-N alloy, which gives excellent physical properties in test bars cast under definite conditions but which when put into castings in the foundry is filled with fine hair cracks on the surface.

In order to obtain sharp castings, i.e., good impressions of the molds, and to fill up all parts of the mold cavity, it is necessary that the alloy should be well fluid when liquid and that it should flow freely and rapidly. This presupposes high fluidity and low viscosity in the alloy, but comparative values for these properties in the case of alloys are scant. Measurements of the fluidity and viscosity of the commercial light aluminum alloys, and the determination of the effect of added elements on these properties, would be found useful in the development and selection of casting alloys.

The reason why water wets a sand mold but why liquid alloys do not is explained by the forces of surface tension and cohesion. Some considerable work has been performed on the surface tension of liquid metals, but this has not yet been extended to alloys, and determinations in respect to the light alloys would serve a useful purpose. It might be added that there is a special surface effect in the case of aluminum-rich and aluminum-containing alloys; viz., the formation of a surface skin owing to oxidation; this skin may be sufficiently strong and tough as to prevent the flow of the alloy into thin parts and sharp angles of a mold on casting. A thin tough adherent film of oxides forms on the surface of some light aluminum alloys on melting, particularly at high temperatures, e. g., in the case of nickel-containing aluminum alloys, and this film may ruin the alloy for casting purposes. A con-

siderable number of determinations have been made, in connection with the experiments reported here, on the surface tension of light aluminum alloys, and it is expected to give the results later.

The latent heat of fusion is an important factor in determining the casting qualities of an alloy, and other conditions being the same the time period required for the solidification of a metal depends upon its latent heat of fusion. The latent heat of fusion of aluminum is the highest of any of the commercial metals, and this explains in part why aluminum and its light alloys remain pasty over a long temperature interval on cooling in the freezing range. Part of the pastiness referred to is owing to oxidation.

The question of thermal expansion of the alloys is important since the thermal expansion is the reverse of the solid contraction. The large solid contraction of the light aluminum alloys causes some of the principal difficulties in foundry practice, giving rise to cracked castings, as well as warped, distorted, and off-size castings. The production of satisfactory castings in aluminum alloys, with a minimum of wasters, depends upon the thorough recognition of the following three factors: (1) The high contraction in volume; (2) the pasty stage which exists near the melting point, and which persists for a relatively long time; and (3) the low strength at elevated temperatures. The first two items have been discussed previously, and as regards the last one it may be said that it is possible to increase the strength of given alloys at high temperatures by the addition of small amounts of certain metals. Thus, additions of 1 to 2 per cent of either manganese, nickel, or iron increase the strength of some light aluminum-copper alloys at elevated temperatures, and this is taken advantage of in foundry practice.

In founding, the usual device employed to secure dense castings is the provision of a casting head of sufficient height and cross section. The usual idea is that a large casting head exerts considerable pressure on the casting and thus leads to increased density. The pressure exerted by an ordinary riser is quite negligible, and its effect is simply to feed liquid alloy

to the casting, thus minimizing the effect of the liquid shrinkage. A riser of an aluminum alloy 2 feet high would exert a pressure of only about 3 pounds per square inch, so that the riser pressure exerted is of no account in influencing the soundness of castings. Of course, this quite small pressure might be sufficient to prevent the escape of gas in the freezing alloy, thus eliminating blowholes.

The question of the effect of pouring temperature upon the contraction of alloys has been discussed previously, and here it is necessary only to add that for aluminum alloys, like other alloys, there is a range of pouring temperature which yields the most satisfactory results both from the point of view of casting and of physical properties. Apparently, an intermediate pouring temperature, is more desirable than a high or low temperature considering all aspects of the problem, but it was found, in the experiments reported, here that the highest values for contraction are given by pouring in an intermediate temperature range. In dealing with the question of the pouring temperature to be employed, the melting temperature must be considered necessarily, and this matter has been discussed above under *Gas Occlusion, and Overheating.* The pouring temperature is determined by the melting point of the alloy, among other factors, and by its viscosity at different temperatures. Thus, high iron in aluminum-copper alloys raises the melting point considerably and apparently greatly increases the viscosity, so that such alloys give much difficulty when cast at the ordinary temperature employed for light aluminum-copper alloys.

The problem of the dissolution of gases by metals and alloys is one which is but little understood as regards the nonferrous class of materials. The fact that castings frequently contain blowholes has led, of course, to the study of the relationships which exist between alloys and gases under various conditions. The light aluminum alloys are normally quite unsound, and the reasons for their relatively great unsoundness as compared with brass and bronze are not understood. In development work in the light alloys, it would serve a useful purpose if the relative soundness of a series

of the alloys on casting was studied. The question of the soundness of alloys is closely connected with their real density, as distinguished from their true theoretical density, and this consideration is important in the selection of aluminum alloys for leakproof parts and for other parts which must be nonporous.

Turner has given much attention to the question of the density of alloys, pointing out that when there is no freezing interval the density is the same whether the metal or alloy is slowly or quickly cooled, but that where there is a freezing interval (i.e., where there is a temperature range between the liquidus and solidus), sand-cast bars give a lower density than chill-cast ones. Thus, slower cooling gives lower density than rapid cooling, and sand-cast bars show expansions when examined by the extensometer. Little is known as to these effects in the case of the light aluminum alloys, and study of the questions seems to be warranted.

The casting properties of the various alloys employed for linear contraction measurements in the present paper cannot be discussed satisfactorily on the basis of the available information, but other properties being equal, the most suitable alloy for foundry work is the one having the least contraction.

i.—Conclusions, and Summary

This paper has given the results of an investigation on the linear contraction of aluminum and a series of light aluminum alloys on pouring into chill molds and sand molds under various definite conditions. The summarized conclusions to be drawn from the whole work may be stated as follows:

(1) The linear contraction of a series of aluminum alloys, covering a rather wide range of chemical composition, was found to vary roughly from about 0.95 to 1.80 per cent, depending upon the chemical composition and other factors.

(2) The wide variation in contraction found for the alloys indicates that it is poor practice to employ any rough figure for the contraction of aluminum alloys in general, since by so doing much difficulty is had in producing master patterns and in obtaining castings with a minimum of wasters

(3) As regards the effect of some metals upon the contraction of aluminum when added in the amount of 8 per cent yielding alloys of the 92:8 Al-X type, four metals are listed as follows in the order of their effect in lowering the contraction; (a) magnesium, (b) copper, (c) tin, and (d) nickel, referring to bars cast, in both chill molds and sand molds.

(4) As regards the effect of some metals when used as substitute for aluminum in the amount of 2 per cent on addition to 92:8 aluminum-copper alloy, giving rise to ternary alloys of the 90:8:2 Al-Cu-X type: Seven metals are listed as follows in the order of their effect in lowering the contraction, referring to chill-cast bars under the conditions of experiment; (a) magnesium, (b) silicon, (c) nickel, (d) tin, (e) zinc, (f) iron, and (g) manganese.

(5) In the case of 0.5-inch square bars poured at 700 degrees Cent. in sand molds, when 2 per cent of metal is added to the 92:8 aluminum-copper alloy as a substitute for aluminum, seven metals are listed as follows in the order of their effect in lowering the contraction; (a) magnesium, (b) silicon, (c) zinc, (d) tin, (e) nickel, (f) iron, and (g) manganese.

(6) Theoretically, if gas occlusion did not occur, the higher the pouring temperature the greater the contraction, since the density of a liquid alloy decreases with increasing temperature and less metal can be held in a mold cavity at a higher temperature than at a lower temperature. Actually, however, pouring at an intermediate temperature gives greater contraction than pouring at a high temperature or a low temperature because of the effect of gas evolution in the case of alloys poured at high temperatures. The evolution of gas referred to causes actual expansion, thus interfering with the normal contraction and yielding less contraction.

(7) Other conditions being the same, the smaller the cross section of a bar, the less the contraction for a given length.

(8) Other conditions being the same, the greater the length for a given size cross section, the less the contraction.

(9) The linear contraction of the alloys is a function of the kind of mold employed, the contraction being greater in chill molds than in sand molds, other conditions being the same.

(10) In sand molds, the contraction in a casting depends upon the contour of the pattern, the mass of the casting, and the size and distribution of the gates and risers, i.e., the method of molding.

(11) Gas occlusion, owing to a high melting temperature, causes less contraction owing to evolution of the gas when the alloy freezes.

(12) The extent to which piping occurs on casting an alloy in an open-top ingot mold is a factor in determining the suitability of an alloy for casting purposes since this is an indication of the contracton in volume. In general, the less the depth of pipe, the less the contraction in volume.

j.—Acknowledgments

The author is indebted to a number of firms and individuals in the light alloy industry for information, suggestions, and materials in connection with this investigation. The author wishes particularly to acknowledge his indebtedness to Wm. H. Dosey, in charge of the foundry at the Carnegie Institute of Technology, and to J. D. Utech of the same foundry, for facilities so freely given for carrying out the tests in sand molds. Acknowledgment is also made in particular to Charles H. Eldridge, formerly assistant metallurgist of the bureau of mines, for the large number of chemical analyses required.

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Casting Automobile Aluminum Radiator Shells

By William A. Mills, Jr., New Rochelle, N. Y.

It seems that in the past aluminum radiator shells have not been favorably considered because of various reasons which have recently been overcome so thoroughly that now it is expected they will come into general big demand because of their light weight, rich appearance and sturdy strength.

Pin holes and lack of luster after the polishing operation were the two big points of contention. The following paragraphs describe the means of overcoming these difficulties and show the practical and economical way of casting aluminum radiator shells where high quality and finish are the important factors.

The equipment required to cast aluminum radiator shells will, of course depend entirely on the production required. If the production is not large, a single aluminum pattern mounted on a follow board with two or three wood flasks is sufficient. In casting these shells, it is the best policy to cast the surface to be polished in the nowel. The nowel should be rammed fairly soft and before placing on the cope, the pattern should be rapped so that it may be lifted in the cope. Few, if any gaggers are necessary if the flask has been well barred. The cope should be rammed fairly hard. If this is done, the pattern can be easily lifted in the cope. The mold should be shaken out as soon as possible after casting, to prevent cracking.

If big production is required, two roll-over jolt pattern draw machines are necessary, one for the nowel and one for the cope. Well ribbed and barred, interchangeable aluminum flasks have been found most satisfactory because of their lightness and durability. With two men on each machine, a large production can be obtained.

There is no particular grade of sand necessary, although the following mixture gives a good smooth casting—one-third No. 00 Albany, one-third Windsor Lock and one-third old sand.

Many suggestions have been offered concerning the proper alloy to be used in manufacturing aluminum radiator shells, but experience has proved an alloy consisting of 94 to 95 aluminum and 5 to 6 copper gives the best results for a high polish and a dense casting. The use of scrap aluminum would involve the foundryman in various troubles, such as porosity, cracked shells and a poor finish generally when polished. If aluminum zinc alloy is used, small pin holes will show up after polishing as the metal must be poured at a fairly high temperature because of the lightness of the casting.

Gating is very important. A French gate at each end of the shell has given very satisfactory results. This necessitates pouring two up, but it means a lower pouring temperature which gives a more solid casting free from blow and pin holes. The metal should be poured as cold as possible forcing it into the mold. To give the correct pouring temperature is impossible, as this depends entirely on the thickness of the metal of the shell. If possible, however, the metal should be poured between 1250 to 1300 degrees Fahr. It is good practice to have metal covered when melting and to be very careful not to overheat.

There are several shells manufactured that are so difficult to cast that production is out of the question. Therefore, it is good policy for the foundrymen to work with the automotive engineers in designing a shell that is practical to cast on a production basis.

Report of Committee on Corrosion of Ferrous Metals

At the 1922 meeting of the American Foundrymen's association held at Rochester, N. Y., a paper was read submitting some general problems* relating to the various effects of corrosion on commercial grades of iron; and upon motion by Dr. Richard Moldenke the suggestions embodied in the paper and ensuing discussion which recommended the establishment of an advisory committee on corrosion was approved by the members present. Subsequently a committee bearing the title "Corrosion of Metals" was appointed by the president of the association. The committee became active about the first week in January and on February 10, 1923, held its first meeting at Cincinnati where a program of work was outlined. It is this program that forms the basis for a report at this time.

Scope of Work

Inasmuch as the membership of the American Foundrymen's association consists of representatives from both the ferrous and nonferrous industries, the committee, as its name implies, was appointed to the task of studying and assembling important corrosion data that may be of vital interest and importance to both of the above mentioned groups within the association.

The committee is essentially interested in the corrosion of different foundry metals and the presenting of the foundrymen's point of view on the subject of corrosion.

The committee first set itself to work in determining what agencies or organizations are actively carrying on corrosion research in this country. Such work as has been found out by the committee is briefly reviewed in appendix I of this report. The organizations referred to are as follows:

National Research council, Washington, D. C. U. S. bureau of standards, Washington, D. C. A. S. T. M. com-

*H. Y. Carson, Study of Corrosion of Cast Iron, A. F. A. Transactions Vol. 30 p. 206, 1922.

mittee A-5 on Corrosion of Iron and Steel. A. S. T. M. Committee B-3 on Corrosion of Nonferrous Metals and Alloys.

The second important step was to get into touch with those in charge of the above mentioned organizations and exchange with them the viewpoint of the foundry people as it relates to the particular corrosion investigations which each is pursuing. The American Foundrymen's association has not set aside funds for doing original investigation. Nor would it seem necessary to do so for those who are already engaged have outlined such excellent programs of research that confusion might result if new technical bodies undertook the same tasks at this time. The advice and co-operation of the American Foundrymen's association has been welcomed and likewise there has been considerable interest manifested by the various groups within the association itself.

Perhaps the most important work done by the committee during its brief existence includes certain suggestions made to the U. S. bureau of standards, concerning the metal specimens that are being buried in various underground locations in the country. Through splendid co-operation between some of the members of the American Foundrymen's association we have succeeded in securing a number of commercial foundry specimens for the above mentioned tests. These specimens include metals that are actually used in underground piping systems such as cast steel fittings, malleable castings, high-test cast iron (semisteel), gray cast-iron pipe with "open" grain structure, gray cast-iron pipe with "close" or "dense" grain structure and centrifugal castings. The U. S. bureau of standards is most anxious to have the longtime tests (which are reviewed in appendix I) made of maximum practical value to all concerned. The extensive use of foundry products for underground work has made it very desirable to get this comprehensive list of foundry metals included in the test.

Some General Considerations

Some one has estimated that considerably more than one million tons of ferrous products, both iron and steel, are annually being converted to rust; and it is entirely possible that

this amount of material is being wasted every year through a lack of adequate understanding of how to prevent corrosion.

While progress in research in the United States has been slow as compared to some other countries, it nevertheless is gaining great headway. More than 1300 American companies have laboratories and about 10,000 men and women are employed in them. Most of our corporations engaged in scientific investigative work have linked up with government agencies, trade and technical organizations and universities in a systematic effort to increase the speed of actual accomplishment through an interchange of ideas. But in spite of the clear advantages that have been shown to result from co-operative research work, dozens of great corporations continue to pay $100,000 a year for legal advice and $10,000 for scientific guidance.

Industrial secrecy, as a brief study of industrial progress throughout the world in recent years will indicate, is the weapon of the business weakling and has done more than all else to retard co-operative research.

In a pursuit of the true fundamentals of corrosion phenomena, the most useful result will probably be obtained by combining the best efforts of those who are most interested in the subject. To this end the foundry people who are interested in the well-known superiority of cast materials to resist corrosion have a direct interest in critical studies of this subject and have also the obligation to contribute their best thoughts to the task of minimizing the evils of corrosion.

Chairman H. Y. Carson and George K. Elliott appeared before the corrosion committee of the National Research council in Washington on April 13, presenting the work of the American Foundrymen's association on corrosion. The need for further co-operative work between the A. F. A. and other organizations was pointed out to the research council committee; also the distinct need that exists for standardizing terms and methods for fundamental corrosion research was discussed with the committee. At the suggestion of Chairman W. M. Corse the research council committee voted to add a representative of the A. F. A.; and the appointment of H. Y. Carson to this post was made by president C. R. Messinger on April 26, 1923.

Need for Accelerated Corrosion Tests

There is a very real and practical need for quick time tests to determine the value of new or untried metals which are being placed on the market from year to year Most, if not all, of the accelerated and laboratory tests have fallen into disrepute for one reason or another. It probably would be difficult to say just why investigators have lost faith in quick time tests, but it may be that the results from the tests have been too generally applied to all other unrelated corrosion phenomena.

Investigators now know that wide differences exist between atmospheric and under water corrosion phenomena. Committee A-5 on corrosion of iron and steel, of the A. S. T. M., through its subcommittee* on total immersion tests, conducted a comprehensive mine water corrosion test on a large number of irons and steels of varying chemical composition. The action of the acid mine water on all of the test specimens was severe. Copper-bearing steel, which proved to be very resistant to atmospheric corrosion, were corroded rapidly by the mine water and it would appear from a study of the data that there are two different types of corrosion phenomena involved in the two cases. Carrying the same reasoning farther into the field of corrosion, it would seem that other variations can be determined and possibly classified into distinct types in line with practical service conditions. For instance, some materials are subjected to alternate sub-aqueous and atmospheric surroundings, while others are in contact with humic acid and stray electric currents, etc., etc. There can probably be found quick time tests which will each serve as a criterion for predicting what will be the result of a long time service test for given conditions or groups of conditions. The thought is here advanced that it may be wise at this time to so parallel all long time tests now being conducted by independent research organizations with accelerated tests so that by the time the long time tests are concluded, much data will have accumulated as to the efficiency of the short time corrosion tests. The work should be so standardized that the results will be comparable and useful to independent research groups.

*Report of sub-committee of committee A-5, on Total Immersion Tests, *Proceedings* A. S. T. M., Vol. 21, 1921, page 157.

Non-Ferrous Metal Corrosion

The effort to determine the effect of corrosion on non-ferrous metals is quite as important as with ferrous materials.

Much good work has been done but has not received as widespread attention perhaps as has been the case with investigation dealing with the rusting of iron and steel. Worthy of attention is a recent report known as Bulletin No. 4 on "Coal Mining Investigations," issued under the auspices of Carnegie Institute of Technology, the United States bureau of mines and the advisory board of coal mine operators and engineers. The attention of all interested in corrosion is directed to this report which involved 45 different metals and alloys.

It is of interest, however, to quote some of the fundamental considerations which are touched upon in the above mentioned report:

"Impervious surface coatings, may, under certain conditions, form on the metal, and protect the underlying metal from further corrosion, or at least greatly retard corrosion. Aluminum and copper, for example, oxidize rapidly in air and form superficial coatings which tend to prevent further corrosion. On the other hand, porous coatings may form which do not protect the underlying metal; and in some instances the corrosion may be accelerated owing to a difference of potential between the metal and the coating.

"It must be remembered that no satisfactory method of making comparative corrosion tests has been standardized. Some materials develop serious local pitting, and may still show a small loss in weight, while other materials corrode uniformly with no pronounced pitting, and in these cases the loss in weight may be relatively large. By considering both the loss in weight per unit-area and the nature of corrosion—whether uniform or irregular—a fair comparison may be made as to the relative worth of the different materials for resisting the corrosive action of acid mine water.

"The method of cleaning the test pieces after the test must also be considered. In most instances the coatings caused by corrosion were removed by rubbing with a fiber brush. However, in some instances they were quite hard and adhered strongly to the metal and in such instances the coatings were not entirely removed before weighing. Such coatings are designated in Table 8 as not removable. In studying the result of the tests, Table 8, describing the appearance of the corroded specimens, should be used in conjunction with those giving the loss in weight and reference should also be made to the photographs.

"Some materials had rather thick, soft, fine-grained coatings. The test specimens during the test appeared as when first immersed except for a change in color and luster. These coatings adhered fairly tight, but could be readily removed with a fiber brush and water.

"A large number of the test specimens had loosely adhering coatings, and these could be readily removed by rinsing in water and rubbing with the hand.

"It seems evident that in some cases the coating acts as a protection against further corrosion, or at least retards the action. This effect was demonstrated in several cases. On several test specimens having hard closely adhering coatings, small portions of the coatings were removed during the course of the test. After the specimens had been removed and cleaned, it was noted that corrosion had proceeded to a greater depth over the areas which had been cleaned at the mine during the course of the test."

It is likewise of considerable interest to note that generally the cast materials in all alloys which were tested formed a "coating removable with difficulty" and showed as a rule "Uniform corrosion."

Ferrous Metals

Perhaps the two groups who are doing most to study the corrosion of iron and steel are: (1) committee A-5 of the A. S. T. M. and (2) the United States bureau of standards. The work of the U. S. Bureau of Standards is reviewed in appendix I of this report, but the work of committee A-5 of the A. S. T. M. has already received such wide publicity that we might well avoid the repetition of reviewing details of their important work here. We desire to say, however, that the A. F. A. has been represented during the past year on committees A-5 and B-3 of the A. S. T. M. by H. Y. Carson and George K. Elliott respectively. It has been important that these contacts were made and the further contact with the National Research council, referred to on preceding page and in Appendix I, permits of almost full co-operation with all organizations in this country who are at present actively engaged in corrosion research.

Recommendations

Our study has lead to the following recommendations which are here submitted for consideration by all parties interested in corrosion matters:

1. All corrosion tests, whether with ferrous or nonferrous metals, should be standardized in such a way that independent investigators may be able to use the same terms to express like phenomena and otherwise use data as it accumulates from time to time.

2. The physics of corrosion phenomena should be agressively studied as have been the chemical and electrochemical phases of corrosion. Such a study is almost sure to reveal more complete knowledge of the subject.

3. The different types of conditions under which corrosion actually takes place should be differentiated. We refer to such types as (1) "completely submerged in an electrolyte," (2) "atmospheric," (3) "alternately submerged and exposed," (4) "in contact with corrosion stimulae," etc. etc.

4. When corrosion research is to be undertaken, extra specimens should, if practicable, be furnished and stored for future study and comparison.

5. Quick time tests should be studied with at least two points of view in mind, namely: (1) checking long time tests, and (2) commercial application in predicting the approximate life of new and untried metals or alloys. It would seem wise for some properly equipped organization, such as the U. S. bureau of standards to undertake in co-operation with National Research council to publish information that will eventually set up standard corrosion practice for both field and laboratory work.

6. One of the most important methods for checking comparative corrosion tests is to measure the *deepest pit* or perforation. Total loss in weight of a given corrosion specimen alone may not be of much value unless upon cleaning the test piece, the metal is ground off the entire surface to a depth equivalent to the depth of the deepest pit.

Respectfully submitted,

WALTER WOOD,

GEORGE K. ELLIOTT,

H. Y. CARSON, *Chairman.*

A. F. A. Committee on Corrosion of Metals.

APPENDIX I

American Research Groups Handling Corrosion Problems

Believing it to be of interest to the members of the A. F. A., we set down in appendix form a brief review of the work of various important organizations which are at present actively engaged in corrosion research.

The National Research council appointed a committee early in 1922 whose purpose it is to serve as a general clearing house and to devote its attention essentially to fundamental scientific study of corrosion.

The American Society for Testing Materials has through its committee A-5 been actively studying the relative corrosion rates of various sheet metals. Many valuable results have been determined and conclusions drawn for copper-bearing steels when subjected uncoated to atmospheric and totally submerged conditions. Further work is being carried out which promises to reveal important fundamentals. H. Y. Carson was appointed in November 1922 to represent the A. F. A. on this committee.

Committee B-3 of the American Society for Testing Materials on the corrosion of nonferrous metals and alloys was organized about one year ago. At its first meeting June 26, 1922, it was decided to leave the research involving actual mechanism of corrosion up to the National Research council committee, and that its first task would be to attempt the standardization of corrosion tests along lines of determining accuracy of work and necessary conditions for applying tests, etc. Only after this preliminary but most necessary work had been accomplished would the committee feel justified in entering upon an actual investigation of the corrosion of nonferrous metals and alloys. At present the committee is studying data covering methods of corrosion testing which were collected by means of a very widely circulated questionnaire. The membership of committee B-3 is large and representative of practically all branches of nonferrous industries. The American Foundrymen's association is fortunate in having a representative member, George K. Elliott, on committee B-3 of the A. S. T. M.

The American Committee on Electrolysis was organized ten years ago through the American Institute of Electrical Engineers. It has in addition to representative members of the Institute and U. S. bureau of standards a large number of other national technical and engineering societies. At the beginning of the co-operative work between these organizations a policy was agreed upon to the effect that the investigations are solely concerned with the accumulation of facts leading to the establishment of principles upon which electrolysis investigation may ultimately be based.

Engineering Foundation has given preliminary consideration to a study of certain peculiar forms of corrosion but it seems likely that these data may be extended and developed by the National Research council and others.

The American Electrochemical society is planning to include in its 1924 program a symposium of corrosion. The National Research council has decided to act as host for a conference on corrosion in the early fall of 1923 preliminary to the meeting of the Electrochemical society in 1924.

The U. S. bureau of mines at its Pittsburgh station is investigating the corrosion of mine waters. A recent publication in which this bureau participated is issued by the Carnegie institute.

Among industrial laboratories of this country which have centered their attention on particular problems of the corrosion of metals are: American Brass Co., Waterbury, Conn.; American Cast Iron Pipe Co., Birmingham, Ala.; American Chemical Paint Co., American Rolling Mill Co., Burdett Mfg. Co., A. M. Byers Co., Dearborn Chemical Co., Duriron Co., Inc., Eastern Malleable Iron Co., Ludlum Steel Co., Lunkenheimer Co., Pennsylvania Railroad Co., Peroline Company of America, and others.

APPENDIX II

Through the courtesy of Mr. Burton McCollum, electrical engineer, department of commerce, bureau of standards, Washington, the following outline of experiments on soil corrosion is herewith presented:

I. Introduction

A. Reason for Tests

In the course of their studies of stray current electrolysis, the engineers of the bureau of standards have frequently had their attention called to cases of corroded pipes in which the electrical measurements taken at the time the corrosion was discovered apparently did not account for the corrosion. In such cases data indicating the extent of the corrosion which might be attributed to soil conditions would be very helpful and the bureau of standards has, therefore, undertaken a study of the action of soils on buried pipe.

B. Interests Co-operating

In this work we have the co-operation of the bureau of soils of the department of agriculture, which has become responsible for the selection of the soils and the determination of their physical and chemical properties; the manufacturers of pipes, who have furnished the materials to be tested; the research subcom-

FIG. 1—SHOWING METHOD OF BURYING MORE THAN 13,000 CORROSION SPECIMENS

mittee of the American committee on electrolysis, through which in many cases, the sites and labor for burying the specimens were secured from local utilities represented on the committee; and a number of other interests that have helped in various ways.

II. Tests on Pipe Materials

A. Size and Arrangement of Specimens

The specimens of pipe are six inches long and from 1½ inches to 6 inches in diameter. To avoid difficulties of protecting the insides of the pipes from accidental corrosion, the amount of which could not be determined, the pipes are filled with the same kind of earth which surrounds them. The cut ends of the pipes are covered with asphalt to prevent galvanic action and to protect the identification numbers. In general, six groups containing two specimens of each material are buried in each test locality, in order that one group may be uncovered from time to time for examination without disturbing the other specimens. The first examination will take place in 1923. The photograph below shows the pipes in the trench ready to be covered.

B. Kinds of Material

Specimens of the following materials have already been buried:

Armoured cable
Butt welded Bessemer steel (2 ounces)
Butt welded wrought iron
Cast iron from northern mines
Cast iron from southern mines
Centrifugal cast iron deLavaud process)
Sand-cast centrifugal pipe
Copper-bearing steel
Duriron
Fibre pipe (for water and gas mains)
Ingot iron
Lap welded open hearth steel
Lap welded open hearth steel
Lap welded wrought iron
Lead cable sheath (small per cent antimony)
Lead pipe

Malleable cast-iron fittings

Semisteel cast-iron fittings

Cast steel fittings.

The bureau of soils has selected the following soils and locations as typical of soil conditions throughout the United States:

States	City	Soil
Alabama	Mobile	Norfolk Fine Sandy Loam
California	Bakersfield	Black alakali
	Buttonwillow	White alkali
	Los Angeles	Hanford Fine Sandy Loam
	Los Angeles	Ramona Loam
	Oakland	Dublin Clay Loam
Colorado	Denver	Unidentified
Delaware	Wilmington	Sassafras Silt Loam
Florida	Jacksonville	Norfolk Sand
	Jacksonville	St. John Sand
Georgia	Atlanta	Cecil Clay Loam
Iowa	Davenport	Muscatine Silt Loam
	Des Moines	Lindley Clay Loam
Louisiana	Bunkie	Swampland
	New Orleans	Muck
	New Orleans	Clay
Maryland	Baltimore	Hagerstown Loam
Massachusetts	Middleboro	Gloucester Sandy Loam
	Norwood	Merrimac Gravelly Sandy Loam
Minnesota	St. Paul	Hempstead Silt Loam
Mississippi	Meridian	Ruston Fine Sandy Loam
	Meridian	Susquehanna Clay
Missouri	Kansas City	Summit Silt Loam
	Kansas City	Marshal Silt Loam
Nebraska	Omaha	Wabash Silt Loam
	Omaha	Knox Silt Loam
New Jersey	Camden	Sassafras Gravelly Sandy Loam
	Elizabeth	Salt Marsh
New York	Rochester	Ontario Loam
North Dakota	Fargo	Fargo Clay Loam

Ohio	Cincinnati	Fairmount Loam
	Cleveland	Allis Loam
	Cleveland	Mahoning Silt Loam
	Sidney	Genesee Silt Loam
	Springfield	Miami Silt Loam
Pennsylvania	Jenkintown	Chester Loam
	Norristown	Penn Silt Loam
Tennessee	Memphis	Memphis Silt Loam
Texas	Dallas	Bell Clay
	San Antonio	Houston Black Clay
Utah	Salt Lake City.	Clay
Virginia	Alexandria	Keyport Loam
Washington	Seattle	Everett Gravelly Sandy Loam
Wisconsin	Milwaukee	Peat
	Milwaukee	Miami Clay Loam
Wyoming	Casper	Alkali Soil

III. Tests of Protective Coatings

The study of corrosion naturally raises the question as to how it can best be retarded or prevented, and an obvious method is to use some protective coating in localities where corrosion is serious. At the request of a certain pipe manufacturer, two specimens of each five pipe coatings were buried in most of the localities chosen for pipe tests. The number of specimens is not sufficient to furnish all the data desired and it is now proposed to extend the original investigation to include a more thorough study of protective coatings, with a view of determining the life of coatings when applied to different pipe material and exposed to various soil conditions.

Two general classes of coatings will be tested, namely, (1) bituminous dips, and (2) metallic coatings. Since it is necessary to limit the tests to those materials which promise the best results and which are most dependable and available, it will be necessary to exclude paints, patented preparations, and coatings which are not yet available on a commercial scale. The bituminous coatings most commonly used are made from asphalts or coal tar pitch.

A. Asphalt Coatings

Tests of six asphaltic dips will give a fair idea of the usefulness of this type of material. These should include Bermundez asphalt with the addition of Gilsonite, Midcontinent asphalt with the addition of stearin pitch, and Mexican, Texas, California and Midcontinent asphalts.

The tests will show the durability of the coatings under five soil conditions; (1) black alkali, (2) white alkali, (3) salt marsh, (4) acid soil, and (5) one neutral soil. In addition, one kind of asphalt will be tested in each of the forty-one other locations where bare pipes have been placed. From this it will probably be possible to estimate the results of each coating in each soil.

B. Fabric Wrapped Specimens

The use of asphalt or pitch impregnated fabric to protect pipe is common and to determine the relative value of such a coating five specimens of pipe protected by fabric treated with one asphaltic material will be buried in each of the forty-six locations. These specimens have been provided for.

C. Pitch Coatings

Coal tar pitches are derived from three principal sources and may be classified as coke oven, coal tar, and water gas pitches. All of these will be tested in each of the five soils mentioned above. The kind of pitch used for protecting pipes is usually that which is manufactured in the locality where the pipes are dipped. Therefore, instead of using a single kind in each of the forty-one other localities, the pitch used will be that most commonly employed in each region. Our data indicate that this calls for eight tests of coke oven, twenty of coal gas, and eighteen of water gas pitches.

D. Effect of the Pipe Material on the Coating

Some pipe manufacturers believe that bituminous coatings adhere better to some kinds of iron than to others. In order to determine whether this is true five specimens of ingot iron as well as Bessemer steel protected by one kind of bituminous coating will be buried in each of the five locations previously mentioned.

E. Preparation of Bituminous Coated Specimens

All coatings should be applied at the optimum temperature by the hot dip process and the pipes should be dipped twice to eliminate pinholes. The pipes to be dipped should be 17 inches long and 1½ inches in diameter. The same thickness of coating should be applied in each case. In order to secure uniform treatment it is hoped to have one maker of pipes dip all of the specimens. Bessemer steel will probably be used.

F. Zinc Coatings

Zinc, lead, aluminum, and tin have been used to protect iron against corrosion due to atmospheric conditions, but zinc applied as galvanizing has been the chief protection against soil corrosion. Lead and aluminum coated pipes are also available.

(*a*) *Galvanized Pipes:* The effect of two possible variables, thickness of the coating and character of base metals, will be determined.

(1) *Effect of Base Material:* To determine the effect of base materials it will probably be sufficient to bury five specimens of one weight of galvanizing applied to Bessemer steel, wrought iron, copper-bearing steel, and ingot iron, in each of the five types of soils selected for the tests of bituminous materials.

Five specimens of galvanizing applied to one of those materials should be buried in each of the other forty-one locations. The coating should have a weight of nearly two ounces per square foot, as it is practical to apply without special manipulation.

(2) *Effect of Thickness of Galvanizing:* Since it is not possible to accurately predetermine the weight of coatings applied to pipes, and since the thickness of the coating will be an important factor, it is proposed to determine the effect of this factor by burying six specimens of sheet material 12 inches long by 6 inches wide, protected by coatings weighing respectively. 0.10, 1.5, 2.0, and 2.5 ounces per square foot, in each of the five soils mentioned above. To prevent injury to the coatings

due to bending the sheets in handling, the coating should be applied to heavy sheet material.

(*b*) *Galvanized Sheet for Underground Tanks:* The investigation of soil corrosion is primarily concerned with the action of soils on pipes. A large amount of sheet metal in the form of tanks and culverts is also exposed to soil action and the bureau has consented to include a few tests of sheet material because it appears that such tests will be of considerable value to the public and can be conducted in connection with the pipe tests much more economically than as an independent investigation. Five specimens of Bessemer steel and an equal number of specimens of ingot iron each protected by galvanizing of the same weight, will be buried in each of the forty-six locations.

G. Lead Coated Pipe

Arrangements have been made for sufficient specimens of lead coated pipe to bury a group of specimens in each of the forty-six locations.

H. Calorized Pipe

Specimens of pipe calorized by the dry process and by the hot dip process will be buried in five soils.

I. Preparation of Specimens

The metallic coatings should be applied to 1½-inch pipes 17 inches long, or to 16-gage strips of sheet metal 12 inches long and 6 inches wide.

IV. Tests on Brass Pipe and Fittings

Brass cocks are commonly used in connection with gas and water services, and it is proposed, therefore, to determine what action various soils have on different brasses used and whether the connecting of brass to iron or lead creates a galvanic couple which is detrimental.

Three kinds of brass are to be tested under five conditions (1) brass pipe, (2) forged fittings, (3) connected to lead, (4) connected to wrought iron, (5) connected to cast iron.

In order that some of the specimens may be uncovered from time to time to determine the progress of corrosion without affecting the other specimens, four groups will be buried in

each locality. Specimens will be buried in each of the forty-six soils where iron pipes are under test. This will require a total of 2760 samples. They will be such that they can be used in connection with ½-inch pipe.

V. Number of Specimens Involved in the Investigation

1.	Pipe Materials: (46 soils x 14 materials x 12 specimens of each material in each soil) ..... =	7728
2.	Asphalt Coatings: (5 specimens per group x 5 soils x 6 asphalts x 41 soils x 1 asphalt) ..... =	355
3.	Preliminary Coated Specimens: ..... =	300
4.	Wrapped Pipe (5 specimens x 46 soils) ..... =	230
5.	Pitch Coatings: (3 pitches x 5 soils x 5 specimens of pitch x 41 soils) ..... =	280
6.	Comparison of Base Materials with Respect to Bituminous Coating: (5 specimens ingot iron x 5 soils) ..... =	25
7.	Galvanized Pipes: (4 materials x 5 soils x 5 specimens) + (1 material x 5 specimens x 41 soils) ..... =	305
8.	Comparison of Weights of Coatings: (3 weights x 5 specimens x 5 soils x 3 materials) ..... =	225
9.	Test of Sheet Material: (3 materials x 5 specimens x 46 soils) ..... =	690
10.	Lead Coated Pipe: (10 specimens x 46 locations) =	460
11.	Calorized Pipe: (2 kinds x 5 specimens x 5 soils) =	50
12.	Brass Fittings: (3 kinds of brass x 4 groups x 5 specimens per group x 46 soils) ..... =	2760
	TOTAL ..... =	13,408

APPENDIX III

Accelerated Corrosion Tests

In addition to the placing of metal specimens in acid mine waters[5], which might well be termed a quick time corrosion test, there have been devised several accelerated laboratory tests[6] for determining the relative efficiency of protective coatings on iron and steel. Some investigators are making use of these same tests to determine the rate of corrosion in the

metal specimens themselves as well as the value of certain protective coatings.

The usual methods for making the tests above referred to are the Preece test[4], the basic lead acetate method[3], the hydrochloric acidantimony choloride method[2], and the salt spray test[1].

For convenience a review of these methods is quoted from Circular No. 80 of the bureau of standards on Protective Metallic Coatings for the Rustproofing of Iron and Steel:

"The Preece test is made by dipping, for a period of one minute each, the carefully cleaned sample in a solution of copper sulphate. The sample is washed in running water and lightly rubbed with clea nwaste between dips, and the appearance of bright adherent copper indicates the end of the test. The solution is prepared by dissolved 36 parts of commercial copper-sulphate crystals in 100 parts of water and then adding some cupric oxide to neturalize any free acid. This solution is diluted with water until its specific gravity is 1.186 at 18 degrees Cent., and it should be used at approximately the same temperature.

"The Hydrochloric-acid antimony-chloride method for determining the amount of coating on galvanized metal is as follows:

"A sufficient number of specimens should be used in each test to have an area of not less than 25 cm^2. (4 square inches). They are weighed (to the nearest milligram) and then dipped in 100 cm^3 (or more if necessary to cover the specimens) of concentrated hydrochloric acid (specific gravity 1.20), to each 100 cm^3 of which has been added 5 cm^3 of a solution made by dissolving 20 g of antimony trioxide in 1000 cm^3 of concentrated hydrochloric acid. The same portion of hydrochloric acid may be used repeatedly up to five times by adding before each immersion an additional 5 cm^3 of the antimony-cholride solution. The samples are immersed in the solution for one minute.

(1)—J. A. Capp: A rational test for Protective Metallic Castings.
(2)—W. A. Patrick and W. H. Walker. A method for testing galvanized iron to replace the Preece Process. J. Ind. Eng. Chem. 3. p. 239.
(3)—J. A. Aupperle: The Determination of Spelter Coatings on Sheets and Wire. A. S. T. M. Proc. 15, II, p. 119.
(4)—W. T. Flanders (and others): "Galvanizing and Tinning, D. Williams & Company, New York.
(5)—See Appendix II of this report.
(6) Circular No. 80 of the U. S. Bureau of Standards on "Protective Metallic Coatings for Rustproofing of Iron and Steel."

They are then washed and scrubbed in running water to remove the deposited antimony, and are dried and reweighed. The loss in weight represents the weight of the zinc coating, which is calculated directly to grams per square decimeter; or to ounces per square foot by multiplying the grams per square decimeter by 0.328 (or for practical purposes, by dividing by 3). Often it may be most convenient, on irregular-shaped parts, to express the weight in grams (or milligrams) per piece, thereby avoiding uncertainty due to the area of a sample.

"The basic lead acetate method is carried out essentially as follows:

"The solution is prepared by dissolving 400 g of crystallized lead acetate in 1 liter of water, to which is then added 4 g of powdered litharge. After shaking, the solution is decantered or filtered and is diluted until the specific gravity is 1.275 at 15.5 degrees Cent. The weighed test specimens are immersed in a sufficient amount of this solution to cover them, and at the end of three minutes are removed and freed from adhering lead by rubbing or brushing lightly. They are again immersed for successive three-minute periods (usually four periods are sufficient), until a bright iron surface is exposed. The specimens are then cleaned, dried and reweighed, the loss in weight representing the weight of the zinc coating.

"The operation of the salt-spray test has received considerable attention at the bureau of standards during the last two years, and although all types of protective coatings have been tested, special attention was given to zinc coatings.

"The test as conducted at the bureau is made in an Alberene stone box, with a glass cover and glass supports for the samples. The construction is indicated in the accompanying diagram. The stone box is inclined so that drops of solution collecting on the cover will run down to the edge instead of dripping on the samples.

"A 20 per cent solution (by weight) of commercial sodium chloride (20 g salt and 80 cm^3 water, or 2 pounds salt and 1 gallon water, filtered if necessary, is used, and with an air

pressure of about 6 or 7 pounds per square inch a very fine mist is produced.

"The compressed air is passed through a glass-wool or cotton plug and then through water to remove oil and dust and to saturate the air with water vapor which prevents concentration of the salt solution and crystallization of the salt on the tips of the atomizer. The baffle plate prevents the salt spray from blowing directly against the test pieces.

"The samples, after being washed with gasoline and ether to remove all grease, are placed in the spray box in a vertical position on the glass rods or strips. They are removed from the bath every 24 hours, washed with water, using a moderately stiff bristle brush, and after drying are carefully examined for the presence of red or yellow iron rust. The first appearance of rust indicates the conclusion of the test, but valuable information may be obtained by continuing the test and observing the extent of the corrosion produced by longer exposure.

"If Albereme stone is not available the box may be made of glass, stoneware, porcelain, waterproofed wood, or any other insoluble and noncorrodible material, and all connections should be of glass or rubber.

Report of Committee on Refractories

Your Committee on Refractories is one of the newer committees of the association, the personnel of which was not completed until January of this year. Owing to the late date at which this committee was named and the business activities of the various members, no meeting has as yet been held. An effort was made to get the committee together at this convention for an organization meeting for the purpose of discussing the purposes of the committee and outlining a program of activities for the coming year. This, however, proved impossible.

However, there has been a meeting called by the Department of Commerce at Washington for May 21 for the purpose of discussing the standardization of sleeves, nozzles, stoppers and runner brick. The manufacturers of these products are to be represented at this meeting and the association's committee on refractories has been requested to be present. It is the intention of the chairman of the committee on refractories to have the members of this committee meet there at that time for an organization meeting.

The function of this committee as outlined at time of appointment was to study the requirements of the foundry industry in the way of refractories, formulate the information and data collected and after being sufficiently informed and familiar with the needs of the foundry industry to draw up a set of specifications for approval of the association. The chairman of this committee is to be the association's representative at meetings of the A. S. T. M. to bring before that body the needs and requirements of our industry in the way of refractories, so that a set of specifications can be drafted that will be mutually satisfactory to the A. S. T. M., the manufacturer and the A. F. A.

I believe that it is a conceded fact that at the present time the foundrymen as a whole do not know just what their requirements are in this matter. In fact very little study has

been given to this subject by foundrymen. The various members of this committee will have a goodly sized job on their hands in studying this matter and collecting data and information sufficient to form conclusions. Just what procedure will be adopted cannot at present be stated. It has been suggested that a questionnaire be prepared and broadcasted, but from my experience on sand reclamation and conservation committee with questionnaires I doubt very much if the amount of information thus collected would in any measure pay for the effort and money expended. However, these and other matters will be thrashed out at our future meeting and we hope to have a report of definite progress at the next convention.

Respectfully submitted,

C. N. RING, *Chairman.*

Apprenticeship in the Foundry

By W. F. Simon, Milwaukee

The writer was reliably informed that a San Francisco representative of the foundry interests was in this locality recently in search of molders to come to that city with promises of steady employment. This incident, and others, indicates that the foundries are sorely in need of molders. This shortage can not be attributed to any single factor but to several. The foundry industry has grown steadily in the past few years. Labor saving machinery has been installed, dispensing to a great degree with the services of the allround molder. As a result little need of continuing apprenticeship training could be seen. While these changes were going on there remained a sufficient supply of real molders in the field but practically all new men coming in were, and have been ever since, men of no particular qualifications, except speed and physical strength—men usually of foreign birth. In short, the demand was for laborers and not for mechanics.

In the meantime, while foundrymen pooh-hoohed the necessity of apprenticeship training, the annual labor turnover among allround molders, due to death and retirement, continued as usual. And today, the "old time" molder has practically disappeared. In other words, we still want horses, in spite of the automobile, but we see no necessity of raising colts.

The Modern Foundry Industry Needs Trained Workers

Some may argue that the molder's trade has been so broken up by machinery and piece work that the molder is no longer needed. The machine shops have suffered no less than the foundries in this respect, but will anyone contend that machinists are no longer needed? It is true that in some types of foundry work it would be folly to employ allround molders. The element of chance in the making of castings is greatly

minimized by well constructed and "fool proof" patterns, and by well designed molding machines. But in the heavier type of work, found in many foundries, the services of real molders becomes necessary. Much depends on the ability of such molders. They must be skilled men with good judgment which comes only after years of experience on a diversified class of work. The value of such men lies in the fact that they need not have the foreman or superintendent stand over them every minute. In the end these prove less expensive in labor turnover costs, and in material spoiled.

Modern mass production necessitates the employment of specialty workers. But there is danger in carrying it too far. We are too likely to overlook the disastrous effects it has on the individual worker. Instead of developing intelligent citizens, craftsmen who take pride in their trade, we are turning out narrow, prejudiced and ignorant workmen, who for want of training, swell the ranks of the unemployed the moment the slightest depression in their particular line of work occurs. But to return to the problem under consideration.

Let us grant that at least a portion of the foundry workers ought to be skilled molders and that apprenticeship training has fallen into decay for various reasons. How can we revive the trade and put it back in its place among the recognized trades?

Employers Too Prone To Let Others Train

Before a beginning can be made foundrymen must agree on a few, though important, preliminaries. What type of work is the journeyman to produce? What course of training, and how long will it take, to develop a journeyman capable of performing the work.

Individual employers of skilled men in any trade readily agree that apprenticeship is vital—that the surest means of making journeymen is in the shop on the job. But not in *their* shop. The biggest problem of apprenticeship is selling the idea to the employer. They do not like to be told this but it is true nevertheless. Probably it is no easy matter to interest him because immediate profits do not exist, or probably because he can

dispense with apprenticeship for the time being and depend on fate or his fellow employers to do the training. At any rate, each foundryman who employs allround molders must agree to give his whole hearted support to the cause or it will hardly pay to begin. Once the employers in a locality have been sold to the idea the job is half completed.

Inducements to Get Apprentices

But where are apprentices to come from? Will boys take to the foundries as soon as foundry operators declare themselves willing to hire apprentices? It must be remembered that there are many other trades, more attractive in outward appearances than the molder's trade, that are only too anxious to secure learners. Because of the nature of the work and because of the attitude of the present day boy toward hard work, the foundries must offer unusual inducements to prospective apprentices. Naturally the matter of wages strikes the average boy as of being of first importance. The beginning wage scale must be somewhat higher than is paid in other metal trades and ought to be nearer that paid for learners in the building trades. For instance machinist apprentices here earn about 20 cents per hour to start with while molder apprentices receive an average of about 38 cents with an increase of about 2 cents per hour every six months.

Unfortunately at present journeymen molders earn little more than piece workers. Perhaps this will adjust itself when later molders are still more in demand. The fact that a molder is assured of continuity of employment, while the piece worker is not, is a good argument to use in persuading boys to learn molding.

The most attractive inducement that any employer can hold out to potential apprentices is to guarantee them a real opportunity to learn the trade. I cannot stress this point too strongly. Any number of young men can be persuaded to enter an apprenticeship with high wages as a bait but not until they have spent several months in it do they realize that genuine interest in them on the part of the employer is much more val-

uable than so much per hour. When it becomes necessary for an apprentice to ask repeatedly for a class of work to which he is entitled but does not receive, or when he sees that he is treated as a helper, or as a necessary nuisance around the shop, he quits in discouragement and leaves the trade entirely or goes to another employer whom he knows will give him proper recognition. These are not theories but facts that we meet with every day. I say therefore, that the employer who can show his apprentices, who earn only 20 cents per hour, that he is sincere in his desire to give them every chance to learn the whole trade, and not depend entirely on the whims of his foreman, will have a more successful apprenticeship system than the employer who pays his apprentices 60 cents per hour but who expects the learner to pick up the trade while performing helper's or laborer's work. Incidentally, an employer who is ready to offer a genuine apprenticeship training ought not to hesitate to put his proposition in writing in the form of an indenture. Let the apprentice and his parents know that it is a bona fide apprenticeship and it will lead to a better understanding on all sides. A bonus of fifty or a hundred dollars at the end of the successful completion of the apprenticeship works wonders.

How to Secure Right Type of Apprentice

A word must be added concerning the problem of securing the right type of apprentice. Too often apprentices are hired because they happen to be at the gate when the job is open, or because they happen to be a relative of an employe. It is surprising to learn how little the average boy knows of the opportunities open to him in the trades. They work at odd jobs that bring no return in training until such time when they can no longer afford to work for apprentice's wages. The time to reach these boys is when they are attending the continuation school. While they might perhaps be too young to perform foundry work, descriptive literature of the industry will at least start many of them to thinking of it. In Milwaukee we reach the older boys as they apply for work at the employment office. By interviewing them and pointing out the advantages of an apprenticeship many are induced to enter the trade as learners.

Space is too short to describe the various plans used in actual teaching of the molder's trade. This, after all, is something that must be worked out in each individual foundry to fit local conditions.

Training at the Coxe Traveling Grate Co.

By L. W. KLEIN, Port Carbon, Pa.

The shortage of skilled molders has been in vogue in the section where our plant is located, and for that reason, we took on molder apprentices, and believe it a very good thing for the following reasons: We educate the boys to our own class of work with a result that they are familiar with the names of the parts and the patterns, and find them more proficient in this respect than when we employ strange molders.

We train our apprentices as follows:

They serve a three year apprenticeship and are not taken on until they are 18 years of age. The first year they are placed with experienced molders as assistants, and in that manner, get a good idea of ramming, gating and dressing molds. They then have core work for six months, and then are put back at molding by themselves until their apprenticeship is finished.

In addition to this training, we enroll them as students in the International Correspondence School of Scranton, Pa., paying part of their tuition, leaving some of the tuition fee to the parents so that they will also take the proper interest in the boy. Monthly reports regarding their progress are received from the school, and the ratings of each boy are sent to me. If the reports do not show favorably, the boy is called to account.

The correspondence course includes, arithmetic, reading working drawings, green sand molding, coremaking, machine molding, dry sand and loam work, foundry appliances, foundry chemistry, cupola practice, making cast iron, malleable casting, steel casting, brass and alloy founding and general appliances and processes.

In regard to the value of employer and apprentice entering into a written apprenticeship agreement, we find that it cannot

be made binding enough. Should an apprentice not have the essentials of making a good molder or should he become disinterested through lack of appreciation of his work, we do not see why the agreement should not be broken.

I do not believe that the development of the molding machine and specialization of labor does away with the need for apprentice training, as there are a good many small foundries, and they will be for all time, doing a general class of foundry work of such a nature and quantity to prohibit being made on a machine. I believe it is the duty of all foundrymen to train apprentices to keep a supply of molders to meet with the demand.

Regarding the length of an apprentice course, we find that three years is enough. On account of not taking a boy until he is 18 years of age and throwing him on his own resources after the three years are up, I have noticed cases, for this reason, where boys began to make rapid headway after their apprenticeship terminated.

The cost is so small and with the many schools affording the proper education for apprentices, I believe it is better to enroll the apprentices in such a school, because co-operation with local school authorities would mean a special training which could not very well be made general.

Training Apprentices

By E. A. Parker, Springfield, O.

In times not very far distant the question as to the advisability of training apprentices would have been an idle one. Almost, if not all, firms considered it a settled policy to indulge in the luxury of one or more apprentices to each department. That times have changed, and conditions also, to such an extent that the question becomes eligible for discussion and of vital import to the country at large, is evident.

In this age of intensive training why should it be thought inadvisable to train the younger generation in the details of foundry practice? We train men for our office in all its various branches. We have produced cost engineers, factory managers, superintendents and foremen and the like by recognizing the advantages of special effort and applying the principles of value in each individual class. If the many evidences of success merit a continuance of this policy we firmly believe it should be extended to take in the manual trades. Personal efficiency courses are needed for the man who wields the shovel as well as by those who use the pen. If special training yields returns in one case it will also in the other.

The advent of special equipment of various kinds has had much to do with weaning the mind away from its earlier conceptions. So much stress has been placed on making every molder a 100 per cent machine that the need of apprentices to carry on the initiative when our present stock of mechanics has been depleted, has been overlooked.

At this writing there is a dirth, in many of our foundries of molders who have been taught to use their brain as well as muscle, and if the intensive training so much in vogue continues to exclude the youth of our foundries it will not be outside our own vision when the decadence of our skilled mechanics will constitute a menace.

The installation of productive or super-productive apparatus in our foundries should not by any means remove the need of apprenticeship in the deeper principles of molding or in meeting the unfolding problems of the day, and in fact can not do so. Not all of our work can be accomplished by mechanical contrivances and there remains the vast field where success is measured only by the individual skill of the trained workman.

In one of our Ohio factories the other day a man applied for a job. When asked where he had previously worked he named the factory where by mechanical principle the most popular car is produced at a very nominal price. On being pressed further as to what he did he exploded—"I put in that damned No. 29 screw." If our aim as foundrymen is only to produce this type of a cog we have no excuse for forcing apprenticeship on our youth. But we believe the higher ideals of the American mind will evolve a better scheme of life, and a partial reversion to, or a better adaptation of, the methods of other days will reveal much of material good for our foundries.

Some Form of Contract Necessary

Should the theory of apprenticeship be ultimately accepted the problem of the contract between employer and apprentice will be found to have real but not insurmountable difficulties. Our youngsters of today have very little inclination to bind themselves to work for a small wage and some inducements as to training and future prospects will have to be devised that more nearly approximate the changed condition of these times. We do not believe the average youth of today is different from the youth of yesterday but he of today has to live under the burden of an increased overhead. If he does not view the apprenticeship in the same light as he does the training of the approved universities it might appear to him as an unequal bondage and unworthy of serious thought. The employer, naturally will not wish to provide training for philanthropic reasons only and will want to see some real return from the effort.

Just what will constitute a fair wage for the apprentice is a matter of real study, a problem of conditions, and the employer having met these conditions must have some guarantee of

a return on his investment. There will develop dead timber in any course of training and in order that the employer would not be tied up to such by a long time contract it has been suggested that contracts between the interested parties should be based upon a recognition of the possibilities of the case and provision should be made for a short probation period, after which at the option of both parties the contract could be renewed for the proper term of service. The trial period might be placed at six months or less. It might be possible to make a practical application of the bonus system to this case should the apprentice fulfil conditions in a suitable and successful manner. If a per cent, based on his weekly wage, should be allocated to a fund that should be his upon a successful termination of his apprenticeship, a sufficient inducement to a closer application to his own and his employer's interests would be provided. That some such written contract, along these or other lines, should be the basis of all effort toward apprenticeship is evident. Its validity is undeniable and the impress of responsibility is with it.

Thorough Training Should Include Work in All Departments

Any system of training devised, to be thorough, should include an apportionment of time in all the various departments of the foundry, but the advisability of such departmental or general apprenticeship might well be the answer to the question "What do you intend to make of him?" If all you are expecting is a furnace man there will be small returns on an investment based on a general instruction policy. In this respect, however, we can but admire the forethought of the management of one of the larger factories of our city, who insisted that their pattern-makers apprentices should be taught the rudiments of the foundry game in order to broaden their vision and develop ideas in conformity with foundry practice. How much the foundrymen of our land would have been spared of disappointing labor and departmental disputes had this practice been general.

It has often been said that no good comes to us unmixed with evil. Our attempts at compulsory education for our youth

can be so designated. Our schools are filled with potential presidents, governors, literary men, bankers, etc., and not only such but with thousands of units that must of necessity fill positions more closely allied to productive labor. These are thrown upon the labor market at an age where their unprofitableness in proportion to a possible wage is apparent. It is possible that an intelligent modification of existing laws, allowing for instance that a lad be permitted to leave the public school at an earlier age on the employer's certification of apprenticeship, would relieve the unequal condition. In later years this failure of the schools to meet the requirements has been recognized and manual training has found place as a means of filling the gap. It is only partially successful. Future jewelers are taught the intricacies of carpentering; future carpenters are initiated into the veiled secrets of the metal industries; and only a few reach the holy of holies—the trade best suited to them.

Training Should Be Given as Much Thought as Other Improvements

Our nation's foundries are daily spending millions in investigating newer methods, analyzing intricate chemical problems, seeking to build on a firmer foundation the structure of metal adaptability and use. In some respects these great institutions resemble, and in some respects surpass, in constructive thought and practice, our noted pioneer universities. It suggests to our mind that a possible fertile field of usefulness, as expressed by the manual training effort, is nullified if these factories that are so advantageously and courageously spending their millions in selfish ends elect to withhold their help from the public school. From our conversations with instructors we have absorbed the thought that they would welcome the interest and co-operation of foundrymen. One instructor has called on executives of our acquaintance asking that school instruction be amplified by employment after school hours. Such action made general might help the situation to a great extent, but we feel it cannot in any way, from the foundrymen's standpoint, equal in results the special training possible under exclusive foundry control.

We like many other employers have allowed the apprentice

to slip away from us. The labor involved in the training of such, measured by the old time standards, has seemed to be unproportionate to the service received. Changing times with new methods, unselfishness combined with practical ideas may bring about a profitable readjustment for us all. It may even be a monument to American industry. We need the apprentices.

Apprenticeship in the Foundry

By F. W. Kirby, Moline, Illinois

Throughout the country there is a rapidly growing suspicion in the minds of a great number of foundrymen that all is not as it should be within the industry. In our programs of advancement and expansion, we seem to have left out, to a large extent, one feature that is of prime importance in connection with the ever increasing volume of castings, that are being called for from our foundries. We seem to have overlooked the necessity of making adequate provision for the training of new help in the trade of molding. If the foundry industry is to continue its growth to a larger place in the general scheme of manufacturing, there must be a constant supply of properly trained help.

During the last twenty or twenty-five years, we have seen many radical changes in the operation of our foundries. We have seen the introduction of the many various types of molding machines, material handling devices, sand cutting and tempering machines, continuous pouring systems, and many other changes, all of which have brought about an entirely new conception of the class of help required in our foundries.

Under the old conditions, a molder was a man who could turn out a perfect casting of any size or kind, almost regardless of the equipment available; his skill was about ninety per cent of the equipment he had to work with. Today in our production foundries the trade has become highly specialized, and divides itself into several branches.

Need for Training Varies

We now have foundries devoting all their efforts to the production of one general type of castings, such as the gas engine foundry, for automobile trade, wherein the system of checking gages and inspection leaves very little chance for

the man operating the molding machine to go very far astray. The largest number of foundries, however, will probably be found operating in connection with manufacturing establishments. In these foundries we find the greatest variety of castings produced, often ranging from medium heavy floor work, down through the range of molding machines of different types, bench work, and on to the very lightest of castings made from match plates on light squeezer machines. In these types of foundries, all kinds of molders are required in large numbers, from the highly skilled all-around man to the specialist. In both of the types of foundries just mentioned, quantity production is an essential requirement.

There is another very important section of the industry devoted to the production of machine tools. In these foundries the castings produced usually average much heavier than those in the foundries referred to above. Also, the number of castings to be made from a given pattern is relatively small, thus making it unprofitable to install highly specialized equipment. It is obvious that while these foundries are classed as production foundries, they require a more skilled type of molders than the others.

Machine Molding Has Not Made Training Unnecessary

The introduction of the molding machine and specialist molding has undoubtedly had its effect on the demand for the skilled molder, but not more so than the introduction of special machine practices has affected the demand for tool makers and machinists. The total number of molders and machinists has increased, and the shortage of finished workmen, or men who must think on their jobs, is as great, or greater, than ever.

Vestibule Training

In the first type of foundry mentioned, it would seem that the policy should be to bear down on the vestibule idea of training help. Each foundry, of course, would have to work this out to fit their own condition. The system should generally involve a short course of intensive training covering a knowledge of the sand condition, care of the pattern equipment and the necessary operation in the making of the molds with that par-

ticular kind of equipment. The training should be in charge of a thoroughly competent mechanic, whose duty it would also be to instill in the apprentice a thorough knowledge of the shop policy. Wherever possible, or practicable, the preliminary training should be carried on separately from the production shop. In all large groups of workmen, there are always a few who make it their particular business to get in touch with the new help, and instruct him thoroughly in just how slow he should work, and in all of the shortcomings of the management.

In the second type of foundry referred to, the vestibule idea could probably be enlarged to cover a more extensive range of training. The general principle to be followed, however, should be the same in both cases for specialty men. In addition to the specialty men, however, it is also necessary to train men who can put up molds with less highly developed equipment. This refers to bench work and floor molding. Those students who, in their preliminary training, indicated the greatest aptitude for the work, should be induced to continue their training further. In many foundries a small section of the production department is reserved for this work. Here the new men are placed in charge of a skilled mechanic who will coach them along, giving them work which requires greater skill as they progress. The length of time required for this training will depend entirely on the aptitude of the worker. A man taken into an instruction department, knowing nothing about the work he is to do, and getting started right, will develop into a skilled operator much quicker than the man who gets his misinformation from a wrong source, and has much to unlearn.

Training For Jobbing Work

In the third type of foundry, the training will be of an entirely different nature. Here the requirements are for skilled, all-around, molders and helpers; the helper often developing into the skilled mechanic. In these foundries there are two practices possible which will develop molders. The first, is of the young man who goes into the foundry as a laborer, is promoted to a molder's helper, and finally is able to take on more or less simple jobs with success, and in due course of time becomes classed as a skilled mechanic. The other practice is

that of carrying out a regular course of apprenticeship for boys just leaving school. The apprenticeship should include coreroom practice, all the different kinds of molding carried on in that particular shop and a study of different molding sands, etc.

Training For Small Foundries

The foregoing suggestions have been in relation to the larger classes of foundries. In the small foundry the problem is necessarily of a different type. Here the training of the new man depends entirely on the activity of the foreman in charge. If he realizes the need for training new help, it is possible for him to carry on the training quite as successfully as the larger foundries, even though he has not the more or less elaborate facilities of the larger institution. In the small foundries there are usually several different kinds of molding operations carried on. Although the majority of the molds will generally be made from hand patterns on the bench, there are often a few molding machines, such as hand squeezers, stripping machines, etc. In these foundries the foreman can usually start the beginner in on a very simple part, giving him the necessary instructions, and following this up frequently with advice and further suggestions, until such time as the beginner has mastered that particular job. If the quantity of castings required from that pattern will allow it, the apprentice will usually have enough confidence in his ability to try for larger output. As he progresses successfully, it will be to the mutual advantage to change the man to other classes of work, and follow the same procedure. In this way the beginner will develop into an all-around production molder in the course of two and a half to four years, depending entirely on the ability of the apprentice and the co-operation of the foreman.

In some small foundries, it has been found successful to have a small class of three or four beginners under the direct supervision of a skilled molder who, in addition to his regular work of making molds, will help the beginners along by giving them suggestions and advice as they show the need for it.

It is advisable to give the molder doing this class of work some additional pay, preferably in the form of a bonus, over and above his regular earnings.

In the small piece-work shops, it is quite often found that the only attention to training new help, is to take the applicant and put him in with a group of experienced molders, and let him sink or swim, giving him the regular piece-work prices for what good castings he might turn out. This method is not only wasteful of effort, and discouraging to the beginner, but seldom results in the man making good. On the other hand, there are records of inexperienced men starting in on a particular job, and in two or three weeks, who with the proper attention from their foreman, find themselves turning out as many good castings on this job as men who have been making the same casting for two or three years.

Questions to Be Answered Before Deciding on Training Policy

In connection with the subject of training molders, there are several questions which confront one, and which have to be answered before a start can be made in our endeavor to encourage the training of molders to carry on the trade. The questions are:

(a) Who should we encourage to take the necessary training to become skilled molders and specialty men?

(b) For how long should the training period last?

(c) What inducement can we offer?

(d) Should a form of contract be used?

There are several sources from which to draw material to supply our needs for specialty molders. In all foundries there are among the men engaged in laboring work, some who gradually pick up considerable knowledge of the work the molders are doing. They do this because they are more intelligent than the average laborer. They realize that the molder's earnings are considerably above their own, and quite frequently they will ask to be given a chance to learn the trade. These men should be encouraged. As a rule they are married and have a home. This is a further inducement to us to help them better their condition, because they usually become our most reliable workmen.

How Employment Department Can Help

If the employment department is functioning properly, young men will be found among the applicants for the rougher forms of labor who will be interested in taking a course of intensive training, in order to increase their earnings later on. These young men will usually be found between the ages of twenty-two and twenty-eight years. They have left school quite early, and have been knocking around from one job to another, without getting anywhere in particular. Many of them have woke up to the fact. Others would like to get married and settle down, but realize that they have no reasonable assurance of being able to earn a living sufficient to support a family. These young men, if given the proper encouragement, soon become good specialty men, and occasionally develop into all-round molders. Many foundries have been very successful in taking in newly arrived immigrants to this country, and notwithstanding their handicap of language, have rapidly developed them into reasonably good specialty men.

Schools Can Supply Material For Apprentice Courses

For the regular foundry apprentice, by which we mean the boy or young man who is willing to serve an apprenticeship in order that he may become a skilled workman, we have to look to the boys leaving school. It is frequently stated that the boys are not going into the foundries. This will be true or not true for us in the same proportion as we make it our business. The chief drawback with connecting up the foundry with the boys leaving school, seems to be the idea that the foundry is not an attractive place, particularly for the boy leaving school. While it is no worse than the steel mill and many other industries, it has not had the romance thrown around it that some other industries have, and, therefore, does not appeal to the adventuresome boys. If the practical foundryman who is interested in this subject will take the matter up with the school authorities in his city, he may find that it is not out of order for him to come before the boys' classes, with an appeal to their imagination, and follow it up with visits of the boys to the foundries.

Time Needed To Train Apprentices

The question of the proper length of training period is not one that can be answered by a hard and fast rule. The length of time would depend entirely on what we were going to teach. Certain fundamentals should be taught to all classes of molders, but after that for specialty molders only enough training to allow them safely to enter production work. The length of time required for these men would necessarily be governed by their aptitude for the work. There is no particular reason for holding a specialty apprentice for a definite length of time, regardless of his progress. In the case of the all-round molder apprentice, the requirements are entirely different, and naturally the training would cover a considerable period of time. The difference in the mentality of the apprentice would again apply, and there is no good reason for holding a man back simply to have him fill out his time. A definite period of time should, however, be placed on all classes of training, in order to obligate the apprentice for a definite period, and to have something definite from which to figure. If the apprentice got along more rapidly than called for, he would only be encouraged by being graduated ahead of time.

Rate of Pay During Training

It is impossible to lay down an exact rate of remuneration for apprentices which would apply in all jobs and communities. In general, it can be taken, however, that the specialty man will have to receive a rate higher than the general apprentice. In many shops the custom for specialty men is to start them in at a rate about equal to the day rate for laborers. This amount usually approximates their previous earnings, and in this way their interest is held until such time as they can be graduated into production. In some other shops where piece-workers have a day rate about equal to sixty per cent of the average piece-work earnings, it is customary to apply this day rate to specialty apprentices. For the general apprentice the rate obviously will not be as high at the start as that of a specialty man. We are living in different times from those of our forefathers, when the boy turned all his earnings

over to his parents, whether or no. In those days it did not make much difference to the boy what his rate was; he did not have the disposition of it. As a safe rule, the boy must have enough to allow him a little spending money, providing he has the proper arrangements at home, and in addition, is able to look forward to regular increases in his earnings at stated times. It is often found advisable to have some kind of a bonus arrangement, payable upon completion of the training period.

There are other inducements, however, than those in the pay envelope which we can offer. We can have a clean, attractive workshop, where everything is in its place, and where a feeling of efficiency and pride will be diffused. The toilet arrangements should be absolutely sanitary and elaborate enough to induce the boy, and other employes, as well, to take some interest in their own appearance. Activities outside the regular working schedule should be encouraged, such as athletic training and contests. This will tend to keep up the interest in the institution.

Why Apprentice Contracts Should Be Made

A formal apprentice contract is a matter of individual preference on the part of the employer. In all cases, however, a reasonable contract should be entered into whenever an apprentice expresses a desire for it. Many employers have an individual contract with all employes. As a general proposition, the contract is good for the following reasons:

(a) For the general apprentices, the contract is more important, inasmuch as it covers not only service, but a period of instruction, and the contract should cover the whole labor relation.

(b) A contract and its discussion impresses the seriousness and importance of the training period, and it dignifies the job.

(c) It is more or less of a guarantee to the apprentice of what he may expect when he reaches the goal of his endeavors.

(d) If entered into with the specialty men over a period of time beyond the training period, it has a steadying effect upon

any inclination he may have to jump to another job upon completion of his training period.

Objectives in Training

In all systems of training foundry apprentices, we should bear in mind that there are two distinct objectives: the first is to develop skilled and semiskilled workers to carry on the work in the several branches of foundry trade; and the other is to provide the proper opportunity for developing future foremen and instructors. In connection with the latter lies our opportunity for co-operation with the manual training schools. Several plans have been tried, combining school and shop work, and in most cases have failed, owing to improper planning, lack of interest, and particularly lack of co-operation between the industry and the schools. At the present time what appears to be the most practicable plan for co-operation with the schools would be through following up the continuation school idea. Under this plan, a limited number of apprentices indentured for a full apprenticeship course in the shop, would attend a continuation school not less than one-half day each week, receiving pay the same as though they were in the shop.

Co-operation With Schools

The school is usually operated in connection with the manual arts training course, as carried on in the local public schools. Here the apprentice would be instructed in mechanical drawing, mathematics, etc. During the course, industrial lectures should be given these students by practical foundrymen, dealing not only with the technical side of the foundry practice, but also instilling in the minds of the students the great possibilities that are before them in the foundry industry. In most cases it is from this type of apprentice we will draw our future foremen. There are one or two technical schools, and a few universities, throughout the country, devoting considerable effort to the organization of foundry engineering courses. As these schools are primarily interested in providing the training necessary for the higher executives in the foundry industry, it becomes a subject apart from that of training molders.

Small Foundries Can Train Workers

There are very few foundries so small that they cannot afford to provide some method of apprenticeship. Molders are not born; they are not turned out of schools or colleges; so the supply must come from elsewhere. If the job were as attractive to the boy as banking, or the profession of medicine or law, then we could expect enough recruits, anxious to get into the trade, and they would also find some means or other of learning; but the facts are that we are constantly faced with a shortage of molders; that the job is not attractive to the young man; that the father does not encourage his son to take up the trade; and finally, that the recruits for the foundry in the last 15 years have been largely from the foreign people. Therefore, it is not only the duty of each management to promote the training of apprentices, but it is the duty of every man in the industry to do so.

Training Foundry Workers

By JOHN GRENNAN, Ann Arbor, Michigan

The men employed in the foundry industry at present range from negroes and foreigners to Americans of average intelligence. The negroes and foreigners are by far the greater in number and make up to a great extent the laborers and semi-skilled workers. There are quite a few skilled American molders, but the supply is being reduced and we find few molders bringing their sons into the foundry to learn their trade. Most molders hope their sons will find more attractive occupation. The foundries have always been forced to pay more wages for the same type of labor than other departments of a manufacturing plant, due to the heavy dirty work. But beyond a small increase for this reason there are few signs of high wages for the reported skill that a first class molder is supposed to have. First class molders are as highly skilled as first class toolmakers or patternmakers. They should be better paid to compensate for the heavier and more disagreeable work they do.

Lack of Incentive

At present what incentive is there for an intelligent boy to become a molder? The high wages paid are mostly to piece workers, who earn them by working hard but need little skill. The wages paid on jobbing work and heavy green and dry sand work, where the skill required makes careful work necessary, are not sufficient to attract intelligent boys. If a boy could become an apprentice toolmaker or patternmaker, would the present wages and environment of a foundry attract him? I believe not.

Any apprentice training must be worth while in an economic way to the trainer and most foundrymen would be quite skeptical about paying the necessary amount to attract good intelligent young men. As far as the foundry is concerned the old type of apprentice is practically gone and there is little hope of bringing him back. If the apprentice is gone and

skill is still required in producing castings there must be some way of passing this skill on. The engineer has taken over the responsibility of passing on a large part of this skill but there is still a great deal left to be passed from one skilled mechanic to another.

At present the proportion of skilled mechanics to the number employed in any foundry is much less than it was twenty years ago and will probably continue to decrease. As the number of skilled mechanics in the foundry decreases their value will be better appreciated.

Some Training Material Available

The labor turnover in the foundry industry is high and in the large number of men working in and passing thru the foundries there no doubt is plenty of good material to make into molders. Where it would be impossible to attract the necessary intelligence into the foundry of its own free will, it no doubt would be possible to sift out of the large number passing thru the necessary intelligence to produce all the skilled molders needed. Due to a great many causes intelligent men often find their way into the foundry for at least temporary employment. With careful selection and proper incentive this intelligence can be induced to stay in the foundry. It is from this source that the foundryman can build up his supply of skilled mechanics.

There are two ways of looking at the problem of developing skilled mechanics. One is, to proceed as in the apprenticeship way which is essentially a training proposition in which the apprentice is more or less inert and it is the business of a trainer to develop this apprentice without any exertion on the part of the apprentice. Another way is to make the development of skill worth while to anyone who cares to put forward the necessary energy to acquire skill. It should be the endeavor of the management to give every laborer in the foundry a chance to become a mechanic and to reward him for his efforts as he increases his skill. A good way to advance laborers would be from yard men, casting cleaners, and cupola laborers to molders' helpers and molders' helpers should be given every chance to learn to mold. It would be best

to pick out the molders that showed themselves capable and willing to instruct laborers and pay them a bonus for instructing. The foreman should be required at regular intervals to check up and report the standing of the men, to some executive. A form could be used to advantage so that the reports would be uniform. These reports should show what new men had been hired and give an estimate as to their value as possible mechanics. It should also show what each old employe had done in the way of advancement.

Every shop has a variety of work such that the skill required to make different castings can be graded. The castings requiring the most skill to make should be made the most desirable jobs in the shop and other jobs graded as to the skill required. If molders' helpers were advanced to the simpler jobs and advanced to better jobs as they learned and openings occurred, molders could be developed in every shop to satisfy its needs. With the molder instructors to advise and a rotation of jobs, a high degree of skill could be developed.

Need for Training Men for Foremen Positions

With the increase in mechanical equipment and technical knowledge required to operate a foundry, comes increased demand for capable executives. The old method of advancing exceptional molders to foremen is no longer satisfactory. A foreman must be more than a good mechanic. The gap between molder and foreman is too wide to expect a molder to become a foreman without training. Good mechanics can be developed from intelligent men who have practically no education. This is not true of foremen. The better education the better prepared a man is to be an executive. It is entirely reasonable to train foremen and all executives in the foundry where they are to be employed and, if advancement to the better positions is open, a higher type of intelligence can be attracted into the foundry. It is not to be expected that the average molder would ever develop into a foundry executive but there will always be an exceptional one here and there who will prepare himself. These exceptional ones will not be enough to fill the demand. It is not reasonable to think that a high school grad-

uate and much less a college graduate would enter a foundry to become a molder. Yet these graduates are far too few in foundry work. A graduate engineer has an education that the foundry as an industry needs. What an engineer needs is a knowledge of molding and other foundry operations to make him of exceptional value to the industry. Large manufacturing plants would do well to work out a plan of developing college men for foundry work in some such a way as they have for their sales force. The college man should go through a rapid apprenticeship course in all the departments. If he possesses executive ability he should be able to advance rapidly once he has become familiar with the details.

It is not to be expected that of the few college men available many will find their way into a foundry and there are very few foundries that are large enough to have executive positions open often enough to attract college men. There are a larger number of high school graduates and if they could be attracted into foundry work by the possibility of advancing to the executive positions the quality of the personnel in the foundry would be better than it is now. A high school graduate should have education enough along general lines so that by applying himself to such special subjects as are needed in the foundry he could develop into a good mechanic or executive. The subjects that should be taken by an apprentice should include mechanical drawing, physics, general chemistry qualitative and quantitative analysis, general metallurgy of iron and steel, and a course in metallography. Economics and cost accounting should also be studied.

Training to Suit Plant Needs

The larger manufacturing plants carry on training with a director in charge but only the larger ones can afford the expense of a specialist to direct their training. In smaller plants the training must be in charge of an executive who has other duties. This executive will not have time to more than stimulate interest in the development of his mechanics. Night schools which can be found in almost any city are the best places to obtain the training for advancement to executive foundry positions. If the town is too small to have a public

school or Y. M. C. A. night school, then the correspondence schools are still available. In case a night school is available with teachers who are not teachers of the subjects desired, but willing to teach it, a combination of correspondence school and night school works well. A firm that cannot afford a director to supervise training can afford to encourage their men by supplying books and paying tuition or by giving a bonus for completing courses.

In order that the executive in charge of training have time to give it some thought, some of his minor duties may be assigned to those he is training. As an example an assistant foreman may have charge of pouring. Part of this work can be assigned to a learner. A minor job may need mounting on a molding machine. Some one may want to take it home and work it out. This training or opportunity to improve should be open to everyone in the foundry and made as competitive as possible. In large cities such as Chicago, Detroit, Cleveland and others that have foundrymen's associations, these associations could promote better training by making training a part of their program.

Industry and the Public Schools

By Arthur B. Mays, Urbana, Illinois

With the development of modern methods of production and the resulting destruction of the traditional form of apprenticeship a serious problem of trade training was created. America has been playing with this problem for over half a century but has never faced it squarely or seemed fully to realize its seriousness or to appreciate its significance to the future development of American industry. Any amount of development of automatic machinery or of scientific factory organization and division of labor will never completely do away with the need of trained workmen. The proportion of trained men may be greatly decreased and the special types of training required may vary greatly from time to time but there will always be the need for large numbers of trained men in every important industry.

In trying to supply this need industry has resorted to various makeshift means, the favorite means for many years being to import men from countries where effective programs of vocational education have been in existence for a long time. Now that this supply is largely unavailable and is likely to be entirely cut off for several years at least, the need for an effective program is again assuming prominence. Various attempts to revive apprenticeship in a modern form, to develop training departments in plants, and to further extend the field of private trade schools have been made. Some such efforts have been reasonably successful, others have been worse than failures, but the big problem is yet to be worked out on a national scale and on a reasonably permanent basis.

Local or plant schemes for solving local or individual plant needs are necessarily temporary and in the long run ineffective. Any careful study of the problem leads almost inevitably to the conclusion that a problem of this character can only be handled in any broad and effective way by public agencies. The wisdom of training engineers, chemists, and

accountants at public expense by public educational agencies is no longer seriously debated. On what grounds then can any question arise in regard to the training of foundrymen, patternmakers, auto mechanics or plumbers at public expense by public agencies? Surely no longer can objection seriously be offered on the ground either of propriety or of public policy. Such objection may be raised occassionally by an old fashioned school superintendent but the objection will soon disappear when employers and intelligent mechanics demand of public education the types of education which they have the right to expect from the public schools. Aside from an apparent indifference on the part of those most concerned, the chief difficulties seem to be those of method and organization.

The Federal Government and Vocational Training

Since 1917 the federal government has been pushing a great national program of promotion of vocational education. In every state in the Union there is a state board of vocational education with a state supervisor of industrial education who is ready and anxious to encourage in any legitimate way the work of training, by public agencies, the boys and men of the state for more effective work in industry. These state boards have funds at their disposal to assist the local communities in their efforts to develop industrial education. Yet the number of school men, employers and labor leaders who appreciate either the possibilities or the significance of this situation is as yet relatively small. This effort on the part of the state and federal governments does not begin to solve the problem. The problem will never be solved till the employers of labor give some very careful attention to it and work out with the school authorities practical co-operative plans. The schools are carrying an enormous burden now, but their history proves that when any large element in society urges their assumption of any important type of education which other agencies have failed adequately to give they respond with the best of their ability. When employers insist on practical training programs for industrial workers the schools will develop these programs.

Local Foundry Groups Can Secure State Co-operation

Much can be done now in any town in the country if the demand is sufficiently urgent. Suppose for example that in some town there is a foundry which has need for a certain number of trained men every year and that there are enough boys or young men who would like to get into this work if proper training facilities were available. If these young men can be employed in some capacity in the foundry the superintendent of schools can at once organize an evening class for these men. He can employ as the teacher of this class one of the best mechanics in the foundry for two or three evenings a week and run the course as long as it is necessary to train the boys. In this case, one-half of the teacher's salary will be paid by the state board of vocational education. If the evening class is not feasible and it is not possible to employ these boys in the foundry during the training period, any boys working anywhere who can be induced to take the course can be offered work on a part-time basis, say for 8, or 12 hours a week. If the foundry is really anxious to promote such a scheme it can lend a high grade man to the school for 8 or 12 hours a week to teach these boys and the federal government through the state board will reimburse the school for one-half the salary of the teacher for the time he devotes to this teaching.

Foundry Employers Should Co-operate With Their Local School Superintendent

These two present possibilities perhaps are far from ideal but they are proving very effective realities in some cities and could be used in many places *if the interested parties* will urge the school superintendent to undertake the job and will then *back him up*. Every possible assistance will be given by the state supervisor of industrial education who is in nearly every state a well trained man.

The whole great problem of industrial education will soon have to be faced by the two great interested institutions, public education and American industry. The solution lies only in a united effort which contemplates a permanent national program.

But the first step seems to be to exploit fully the present possibilities and from them to gain experience upon which to build the larger program.

Training Foundrymen at the University of Minnesota

By O. W. Potter, Minneapolis, Minnesota

In the spring of 1921, a committee, appointed by the Twin City Foundrymen's association, conferred with the extension division of the University of Minnesota and after some negotiations, arrangements were made to offer an evening class in foundry practice.

In the fall, at the opening of the school year, this course was advertised through and largely by the members of the Twin City Foundrymen's association. At the opening meeting, Thursday evening, September 29, there were over thirty in attendance. Some of these dropped out and some new ones came in during the enrollment period of two weeks so that the class finally got under way with thirty registered students for the first semester. There were twenty registered students in the second semester.

It was indeed interesting to note the different branches of the foundry industry represented in this class. First there were represented the iron foundry, the brass foundry, and the steel foundry as follows:

	First Semester	Second Semester
Iron	20	16
Brass	2	1
Steel	7	3
Casting Users	1	..
	30	20

The various branches represented were as follows:

	First Semester	Second Semester
Molders	5	8
Coremakers	1	1

Clerks	3	1
Draftsmen	2	2
Superintend. and Foremen	14	6
Purchasing agents	1	2
Metallurgists	1	..
Casting users	1	..
Salesmen	1	..
Patternmakers	1	..
	30	20

It was interesting further to note that these men came from small shops and large shops, from manufacturing companies who had their own foundries and from jobbing foundries.

Then too, the degree of previous education varied greatly, some not having the equivalent of a common school education and others being college graduates.

Preparation of Training Course

With this condition confronting us, we proceeded to prepare a course such as we felt these men needed with the idea of keeping everybody's interest and giving them a boiled down, concise set of notes, written in as simple language as possible. It would have been an ideal condition if there had been sufficient registrations so that a section could have been formed for the iron foundrymen, the brass foundrymen, and the steel foundrymen, but since this was not possible, it was necessary to deal somewhat in generalities. Then, too, we felt that no harm was done in informing the brass foundrymen of some of the phases of an iron foundry and the steel foundry and so on.

This class was held in one of the class rooms of the Engineering College on Thursday night from 7:30 to 9:30 for 17 weeks and then a continuation course was offered for another 17 weeks. Since all of the men registered were shopmen, the course was composed of lectures and discussions. A system of exchanging questions was tried and proved very successful. At each meeting of the class, the students were given

several questions to work on during the week. The students also handed in questions each week for the instructor to answer. At the following meeting of the class, these questions were brought up in open discussion which proved very interesting and instructive to all. All students were urged to participate in the discussion and this they usually did when it came time to discuss their question. By having the various branches of the foundry industry represented, it was possible to get several points of view; it even brought out some very heated discussions. In this way over 200 practical questions were brought up and discussed. A few sample questions are listed below:

What is a standard method of shellacing a pattern in different colors and what do the various colors represent?

Do you think molders and coremakers with a good general knowledge of foundry operations make better workmen?

What is the general course of procedure and remedy for porous gear blanks in steel?

Why is there so much suspicion around a foundry and why is it so hard to introduce new things?

What do you think of the necessity of having welding apparatus in a steel foundry?

What would be the specifications for easy flowing gray iron suitable for pouring very thin castings?

How is the location of cupola tuyeres determined?

What are the desirable and undesirable effects of copper in cast iron?

How do you proceed to figure weights when only patterns are available?

What are the advantages and disadvantages of sand cast and machine cast pig iron?

What simple shop tests can be made in testing molding sands?

Explain how silicon controls the hardness of cast iron by its effect on the carbon.

Following the discussion, a short recess was declared so that everybody could exercise a little, as sitting still for two hours after a hard day's work is not the easiest thing to do

After the recess, the regular outlined course was followed. The students were furnished with typewritten copies of each lecture and only occasionally were they required to take any notes. These lectures were illustrated by blue prints and blackboard examples.

Special work and problems for outside work were assigned to all and upon request additional examples were furnished for practice. Each student was credited with the amount of work done outside and at the end of the course was given a mark of standing on the basis of A, B, C, D, and I, or the regular collegiate method of grading.

The outlined course followed in the lecture work was as follows:

1. *Drawing.* Reading blue prints, figuring weights, checking patterns and core boxes.

2. *Materials.* Physical and chemical properties, specifications.

3. *Metallurgy.* Foundry chemistry, sampling, mixtures, melting practice, testing bars, etc.

4. *Sands, Refractories and Fluxes.* Physical and chemical properties and applications.

5. *Foundry Economics.* Defective castings, melting loses, refuse, etc.

6. *Foundry Machinery.* General discussion.

7. *Foundry Office Practice.* Simple forms, records, estimates, etc.

These data were compiled from all available sources, some of which were *The Foundry, The Transactions* of the American Foundrymen's association, and *Transactions and Specifications* of the American Society of Testing Material, catalogs, and data sheets furnished by foundry supply and equipment dealers.

It is a general condition in evening classes that there will always be some who will drop out especially in the spring of the year. The average attendance, however, showed a good interest in the class. This was 19.8 in the first semester with 30 enrolled and 11 in the second with 20 enrolled.

After the course was well started, letters were sent out to the firms who had representatives in the class asking for criticisms and suggestions. Out of those that replied, there were some helpful and constructive suggestions and criticisms. Some suggested the segregation of the class into iron foundry, steel foundry, and brass foundry. Another suggested having outside men with wide experience lecture to the class and others an advanced class in foundry metallurgy and research. These suggestions were gratefully received and they were followed in as much as conditions permitted.

Foremen Not the Only Ones to Be Given Training

Later on toward the close of the course, letters were sent out to some of the members of the class asking for their opinion of the course and we received a number of letters commending our course very highly.

Our problem now is to keep this before the foundry owners, superintendents, foremen, and employes and make them realize the opportunity that is offered them. One idea that we find we have to overcome is, that "foremen are the only ones that can profit by this course." This year's experience has shown us that those that can very materially profit by such a course may be listed as follows:

1—Molders
2—Coremakers
3—Apprentices
4—Foremen
5—Superintendents
6—Patternmakers
7—Purchasing agents
8—Draftsmen
9—Melters
10—Clerks and Timekeepers
11—Pattern Storage Clerks
12—Engineers
13—Salesmen
14—Foundry owners
15—Casting users
16—Machinists

It has become a common practice for business men and craftsmen of other lines to take up various lines of study. Machinists take courses of study in drawing, shop mathematics, machine design, and such like; office men take up bookkeeping, accounting, costs, business law, etc. If such courses are beneficial to these men, why cannot foundrymen benefit by a properly designed course? Do we realize the urgent need for some system of education for foundry employes? The foundry industry is one of the largest in the country if taken separate as a unit, yet there has been comparatively little offered to educate the foundry employes in foundry problems.

Foundry Training Has Been Neglected

The foundry has been treated pretty much as a necessary evil in connection with manufacturing. In our college courses, they are usually handled in connection with mechanical engineering and hardly more than a passing mention is made of foundry problems. The foundry in connection with our colleges has without question been below the standard of other courses as a whole. This is not the fault of the educational institutions, however, as there has been no demand for foundry training either from individuals or the industry.

The foundry as a whole seems to be content to struggle along the best way possible when the aid of the greatest educational system in the world could be used to inform and improve the general knowledge of foundry employes. There are two old sayings, "Ignorance is bliss," and "What you don't know won't hurt you." The way so many foundries and foundrymen ride along in "ignorant bliss" is astonishing. If they only knew or realized what unnecessary losses they were having, they would be more ready to inform themselves. How easy it is to ride along till one gets in trouble "head over heels" before any attempt is made to inform oneself, and then there are hurry up calls for help at any price. The price of some of these calls would pay for a very elaborate system of education. Foundry troubles will probably never be entirely eliminated but they can be greatly reduced and anticipated and considerable expense and trouble avoided.

Different Courses Which Can Be Given

Just what kind of a course to offer and how to give it is a problem which we must solve. Some such arrangement as this might be made:

1. Plant short courses.
2. A general course in elementary foundry practice from a technical standpoint.
3. General lecture course by experts.
4. Advance technical course in metallurgy.
5. Research and experimental work.
6. Apprenticeship training.

(1) This could consist of short courses offered at the individual plants possibly at noon time. This would be one of the best ways to arouse interest in education and would no doubt be the start of many taking up some or all of the other courses.

(2) The general course would be open to everybody around a foundry and would be especially helpful because of the exchange of ideas of the various associated crafts. It would also bring about the mingling of foremen, superintendents, and proprietors with their men and thus bring a closer co-operation. This course would be so elementary that all could understand it with only the commonest education yet it can deal with important everyday foundry problems that will be helpful to those with advanced training.

(3) A general lecture course then could be offered to the same general group as for the above course. This course would consist of a series of lectures by outside parties who are experts along certain lines. Supply and equipment dealers have such men who would be glad of an opportunity to aid the industry by such a lecture.

(4) This course would especially appeal to foremen, superintendents, and engineers and could consist of a systematic study of metallurgical problems as presented by the various recognized authorities. This would tend to standardize metallurgical practice.

(5) Research and experimental work should be carried on in every community. Now only the large shops can afford

this but if it were handled jointly through an educational institution like a state university all foundries, regardless of their size, could benefit by this research at a nominal expense.

(6) Apprentices are almost a thing of the past and one often hears now, "What are we going to do for mechanics?" A school where a person could learn how to make molds and at the same time get the technical side would solve the problem. It is obvious that a carefully planned course for an apprentice could furnish the industry with good mechanics in a much shorter time than under the old apprenticeship scheme.

Special Inducements Needed to Secure Foundry Training Material

Right here is where the most careful thought and consideration should be given by the industry. Did you ever stop to think that the molder's trade is dirty, hard work and requires head work to produce good castings? Yet the molder's rate as a craft is considerably below that of the brick layer, plasterer, carpenter, steam fitter, steel worker, and so on down the line. No wonder we cannot attract young fellows to the foundry; we don't offer anything. The molder and coremaker should be rated higher as a craft and more could then be expected of them.

Now having courses outlined, the next problem is to put them into use and get the foundrymen to avail themselves of these courses. This is strictly up to the foundrymen as an industry. Every foundry community should have a live and active foundrymen's association which would co-operate with the local educational institutions in preparing and carrynig out such a program. We should remember it is the industry that is benefitting and they, therefore, should take the initiative, not the school system. The public schools are our servants and will offer any subject which the taxpayers want. It is, therefore, necessary that the directors or leaders of the foundry industry must first be convinced of the idea of the need of a source of education and they must then urge the various foundry associations to back this educational move morally, financially and by taking a thorough and active interest to the extent of a constant advertising program and of working to

the end of having every foundry employe improve his foundry education. When this is done, there is no question but what the industry will be benefitted financially and put on a sounder and more intelligent basis. The educational institutions will then realize that the foundry business really amounts to something and infinite more attention will be given to it and the laboratories and experimental departments will be thrown open to the foundry industry the same as it has to mining, chemistry, electricity, etc. The University of Minnesota is ready to do its duty when the industry finds what it wants and is willing to back it up by something more than talk.

A Plan for the Education and Training of Workers and Apprentices

By L. A. Hartley, Lincoln, Nebraska

America is facing a crisis the nature and gravity of which is realized by comparatively few persons. This country has been gradually changing from one which exported the raw materials from its farms, forests and mines to a manufacturing nation. Our industrial future depends upon our development of manufacturing and this necessitates a greater use of human labor.

In the midst of our industrial development our skilled labor supply is diminishing. The increasing demand for skilled and semi-skilled labor was formerly met by European immigration. This decrease of the labor supply is due in part to changed working and political conditions in Europe. Shortage of skilled labor in America is due also to restricted immigration. Whatever may be our opinion upon this latter question, the fact remains that the tendency is in the direction of greater restriction.

With the return of Europe to a state of equilibrium we must be prepared to rely upon our own resources for labor and also to compete in the world's markets. A continued shortage of skilled and semi-skilled labor will destroy our nation's markets for the same reason that a firm loses its customers if its product is below the standard of quality to be purchased elsewhere at the same price or if its prices are unfavorable.

Our future prosperity depends upon our growth as a manufacturing country. This growth in turn is absolutely dependent upon our constant development of skilled labor.

Just as surely as American industry fails to adopt a systematic method of education and training of workers and apprentices, so surely will this nation enter upon a period of re-

(Credit is given to managements of certain plants where sections of this plan are functioning. Information concerning courses, special methods or results obtained will be furnished upon request.)

trogression and manufacturing decadence. The day has come when the human factor in industry must receive the same scientific consideration as has formerly been given to materials and operations.

The crying need of America is not for more mechanics, it is for better mechanics. If this need is not recognized and met, prior to the stabilization of Europe, the most liberal immigration laws will not save us from the results of our short sightedness. Industrial leaders should not commit the fatal error of confining their attention to endeavoring to turn back the tide of public opinion relative to immigration.

If our skilled labor supply is allowed to become depleted, the effect will be to prolong and intensify the present period of depression. Whether we act now or later there is but one solution to our nation's industrial problem—that is, the organization of a systematic form of education and training of workers and apprentices.

This serious situation is particularly true with reference to the metal trades, the largest American industry from the standpoint of the number of employes and of the value of its product. Skilled labor shortage will result in increased waste in this great industry.

Waste in Industry

While scattered attempts had been made to determine the amount of waste in industry and its causes, it was not until 1921 that any comprehensive data were gathered dealing with this question. An extensive investigation was instituted by a committee on Elimination of Waste in Industry appointed by the Federated American Engineering Societies, of which Herbert Hoover was the first president. The results of this investigation were published in the book, "Waste in Industry," McGraw-Hill Book Company, New York. With the permission of the authors, extracts from this report are included in this paper.

WASTE IN INDUSTRY

From first table, page 9, "Waste in Industry"

Industry Studied	Totals (of waste) Points*
Men's Clothing Manufacturing	63.78
Building Industry	53.00
Printing	57.61
Boot and Shoe Manufacturing	40.93
Metal Trades	28.66
Textile Manufacturing	49.20

While the metal trades show the fewest points of waste of the six industries studied yet in an intensive study of fifteen metal trades plants, the visible waste was found to range from 6 per cent to 56 per cent. No relation was found to exist between the size of the plant and the percentage of visible waste. See Table I.

Table I

From Fig. 1, Page 212, "Waste in Industry"

Plant	No. of Employes	Visible Waste Per cent
1	20,000	41
13	8,450	31
9	7,200	19
3	6,000	42
8	1,500	22
11	1,000	12
4	1,000	44
10	450	23
7	450	17
15	325	23
6	200	40
2	180	6
14	125	19
12	75	56
5	50	30

If American industry is to stem the tide of intensified European competition, we must not only proceed at once to eliminate present wasteful practices but we must provide for continued improvements.

In view of the increasing need for skilled labor and the influence of the human factor upon every other factor in industry it naturally follows that education and training should

* The relative responsibilities have been evaluated in "Points." A theoretical total of 100 points represents all possible waste. As no plant is or could be entirely wasteful the number of points assigned in any case must be less than 100.

materially affect the labor situation and reduce the causes of waste.

Kind of Education to Be Encouraged

What kind of education and training should be encouraged and how may it best be introduced?

In reality education and training activities have for years been carried on in every industrial establishment in America. The great school of experience has a class room where every human being is enrolled. Whether or not education and training should be provided in industry is not a debatable question. A method is already in operation. Its shortcomings have long been realized and the question for debate is how to improve it.

Before an old method is replaced its strong and weak points should be understood, otherwise another scheme equally ineffective may be introduced.

Impressionable young persons, working beside older men with warped views of life and illogical economic beliefs, cannot be expected to develop sane political and economic opinions. Right thinking working men have been abandoned by their natural leaders; managers, superintendents and foremen, to the doubtful leadership of Tom, Dick and Harry.

When the inefficiency of the haphazard methods of training by experience was realized, it was thought that the public schools might be able to offer in an organized form the instruction needed by workers. Those manufacturers who hoped for adequate assistance from the regular public schools have been disappointed. Managements may not thus easily shift the burden of their responsibility to the shoulders of the public school authorities. School men are not easily convinced of the need for developing in children, skill in industrial operations. They cannot know what skill is required in industry either by children or by mature workers.

They are convinced of the need for college preparation and the real aim of most technical high school shop courses is to provide laboratory experience preparatory to entrance upon a college engineering course. No one can question the great value to industry from this laboratory training and there is need today for extension of these activities but school shops

neither possess adequate equipment nor competent instructors to attempt to produce skilled workers for industry.

Finally when considering the public school as a means for training workers, there should be considered the cold facts of student turnover, or as the school man knows it, educational mortality. Only 15 per cent of the children 16 years of age are in school, 87 per cent of those who enter the first grade do not finish high school.

Public school funds may be used to train the employes in industry as will be set up later, but it cannot be done effectively and completely in the regular grades and high schools.

Can the apprenticeship system be made more general so that it will supply the necessary skill together with American ideals? The American railways have for many years maintained quite general and fairly uniform apprentice systems in connection with their shop trades and yet there is general agreement that the railway mechanic of the present is far less skillful than his predecessor. Superintendents, master mechanics, foremen and even labor union officials are almost unanimous in the statement that high class railway mechanics are becoming increasingly scarce.

The original apprentice system which placed one worker directly in charge of one master workman who assumed a direct responsibility for the training of the apprentice is no longer possible in factories where every foreman is responsible for many times more product than the original master of a trade. In addition, managerial control and trade agreement further reduce the feeling of personal responsibility for apprentice instruction upon the part of the foreman.

If we may not look to publicly administered vocational education and if the apprenticeship system as such has failed to function adequately in one of the most important American industries, where then shall we turn in our search of a means by which the education and training of workers and apprentices may be carried on effectively?

If we are to be successful in our serious attempt to supply skilled labor we must interest every human agency in our project.

The aim must be inclusive enough to interest all persons whose co-operation is essential to success.

The constant dream of the human race has been to lengthen the span of life and conquer disease. If tomorrow some great healer should stretch forth his hand and all disease should vanish from the earth, our period of rejoicing would be shortly followed by the most terrible famine imaginable.

The vehement idealist who advocates the abolishment of war, disease and poverty while opposing systems of training which tend toward decreased expenditure of energy and increased production is giving ample evidence of the inconsistency of his aims.

Inducements to Workers

With the goal of training decided upon, the management will need to seek a means of interesting workers. The percentage of workers who are socially minded is no greater than that among managements of industries. While production as a social ideal must be our goal, we must not expect workers to accept this ideal unless they are convinced that managements are sharing the same aim. Steps should be taken at once to prove to serious minded workers that managements propose to do their part in the development of the human factor in industry.

There is just one inducement which will appeal to the great majority of energetic workers. That incentive is opportunity for advancement. Every industry should provide an avenue through which the humblest worker could glimpse his opportunity to rise to the highest position. The blind alleys of industry are the hot beds of discontentment.

Industrial unrest is but the noise of random effort made by the worker as he searches for the key to the industrial blind alley.

Opportunity for advancement can be made possible only through the close co-operation of a great number of plants in an industry. The United States is a nation of small factories. In the metal trades industry for example, there are nearly 17,000 machine shops and foundries, the average of which employ less than 100 persons. Since this is true it becomes evi-

dent that a system which is to function in a large industry like the metal trades with its two million employes, must not be patterned after a plan which has apparently succeeded in a large factory. The system must be equally adaptable to large and small plants in various sections of the country.

Standards of instruction should be formulated and continually revised in accordance with experience and growth. Courses of study should be based upon operations and processes as they are encountered in the various types of factories. They should set up clearly also just what related science, drawing and mathematics are required in order to successfully perform the operations.

Text books should not be relied upon for use in instruction since these for the most part are too general. Lesson material should be prepared for use in each plant and should be as much a part of plant property as are plans and specifications. This will enable individual plants to teach certain plant practices which are considered secret processes.

There can be no objection to the use of text books by the teacher in preparing lesson plans but lesson material should be based upon the teacher's experience and the student's needs.

Just as a foreman may be required to give daily instruction to a number of workers who are doing many different jobs, so will an industrial instructor find it necessary to give individual instruction.

Individual instruction cannot be accomplished by class lectures or demonstrations. Group discussion is valuable but should not be used exclusively. The lesson outline system of instruction combines the advantages of the correspondence school lesson sheet with that of personal supervision of the teacher while the student is gaining the experience which insures application of the instruction.

Instruction Which Should be Given

In the form of the lesson outline recommended, the instructional material is arranged in the order of the three regular teaching steps. (1) Preparation of the mind, (2) Presentation of the idea, (3) Application of the idea. This is easily possible through the organization of material as intro-

ductory remarks wherein the student's interest is stimulated, the class work or drill wherein the student follows directions and acquires skill in performance, and the unassisted practice wherein the student demonstrates his understanding and acquired skill in performance.

This method of preparing lesson material is essential in view of the fact that practically all available teachers need assistance in selecting or organizing their material.

Training foremen in the art of teaching is a most necessary part of any program which aims at increasing skill. The only means whereby skill can be obtained is through practice on the job. Foreman training must therefore include a thoroughly practical training in the art of quickly and surely conveying ideas to workers and apprentices.

There are six separate activities which may be set up in local plants, each one of which will contribute to an adequate system of education and training. A seventh activity, the organization of a bureau to serve all the plants of an industry will be necessary to the complete success of the activities suggested for local plants.

One: The *preparation* of a *flow chart* of worker advancement. From this flow chart those operations and processes presenting greatest difficulty in advancement may be noted. These should be first to receive attention. These impediments to human progress should be carefully analyzed with a view to recording the following details:

1—Mathematics necessary or helpful.
2—Chemistry necessary or helpful.
3—Physics necessary or helpful.
4—Drawing necessary or helpful.
5—Other subjects necessary or helpful.
6—Description of operation or process.
7—Degree of skill required.
8—Period of time usually required to develop skill.

Two: The *organization* of a *foreman training course* in which definite projects are chosen or assigned and one of the objectives of which is the completion of the flow chart. The foreman training course should be extended to include the arrangement of courses of instruction and the preparation of lesson outlines.

Three: *The organization* of *evening* and *part-time instruction* in *related* and *occupational subjects* with foremen, superintendents and members of the engineering force serving as teachers wherever possible. There are many persons in the teaching profession who formerly were employed in industrial pursuits. Many of these persons would welcome an opportunity to contribute to the education of workers in their former pursuits. They should be allowed to extend their service but should be guided into practical lines of effort.

Four: *Formal recognition* of every *department* of the *plant* as an *education* and *training department.* Foremen and sub-foremen should be informed of their responsibility for the education and training of the workers of their departments. Full time instruction and training should be inaugurated and every worker enrolled as a student. Production errors should be recognized as instructional errors whenever there is evidence of failure to properly instruct. Rewards should be provided for foremen who are particularly successful in imparting information. Frequent conferences should be conducted, the aim of which is to improve education and training methods.

The carrying out of this vital work, including the measuring of the foreman's ability as a production teacher and practical assistance and encouragement to him will necessitate as careful though not as extensive reports as are now considered essential in caring for materials in a plant.

Five: *Organization* of an *examination committee* to be composed preferably of representatives of both management and workers in each trade or pursuit. This committee should be responsible for setting up standards of performance and should issue certificates as a recognition of ability in various occupations. This committee should examine candidates for certificates and pass upon credits and make final recommendations for the issuance of certificates.

Six: *Provision* of *opportunity* for *advancement* for all those who have been found qualified. Care should be exercised that no one is allowed to advance until the job he is on is thoroughly mastered.

Every promotion should be earned beyond question and a person's attitude toward production as a social ideal should enter into the consideration of every advancement. Certificates mentioned under "Five" should be given only when skill in performance has been demonstrated for a satisfactory period of time. Workers should be made to feel that these certificates are evidence of general character as well as of knowledge and skill in operation. In other words the same general rules should apply to certification and advancement in industry as apply to certification and advancement in the academic field.

These six activities in the education and training of workers and apprentices will be more readily accomplished by the addition of the seventh one—the establishment of an industrial bureau whose representatives can not only sell the idea of industrial education to local managers but who can demonstrate its effectiveness through the organization of education and training. They also should be able to interest the public school authorities and thus secure a measure of that financial assistance to which industry is entitled through appropriation for vocational education.

To summarize—the plan recommended for the education and training of workers and apprentices includes seven activities:

1—Preparation of a flow chart of possible worker advancement.
2—Organization of a foreman training course.
3.—Organization of evening and part-time instruction.
4.—Formal recognition of every department as an education and training department, that is, establishment of full time instruction.
5.—Organization of an examination committee.
6—Provision of opportunity for advancement.
7—Establishment of an industrial education and training bureau.

How Plan Functions

A brief description of the functioning of this plan is added. It is realized that a plan that has been adapted to many plants with hundreds of classes can not be fully described in one short paper.

Nearly fifty foreman training courses have been conducted in accordance with this plan. Several thousand workers in varied industries have received instruction and training in full time classes taught by foremen who recognized their responsi-

bility as instructors. These full time classes were not assembled, the workers in each gang receiving instruction as they needed it on the job. In most cases workers did not know that they were considered to be students. The difference resulting from the establishment of this activity was the improvement in methods of instruction and the organization of teaching material. This improvement has been entirely due to teacher training for foremen.

While only one flow chart has been prepared in accordance with this plan, the conditions under which it was prepared make it of interest. The plant is one of the largest of its kind in the world. The department for which the chart was prepared is one of the largest in the plant and does not offer exceptional opportunity for advancement. As a direct result of the preparation and use of this chart practically the whole plant has been placed upon an education and training basis. This is a metal trades establishment having a foundry, machine shop, electrical shop, power plant, blast furnace and other departments which complicate the education and training activities. It is operated under the open shop plan.

The conditions surrounding education and training in this plant are in strong contrast to the conditions under which evening school activities are carried on in the Omaha Labor Temple as an extension of the local public schools in co-operation with the Nebraska State Board for Vocational Education.

The Central Labor Union takes active interest in the instruction which is kept strictly supplemental to the daily work of students. Instruction has been carried forward continually during the past year and a half without interruption during the summer months. One class illustrates this type of work.

A class from Iron Molders Union No. 190 met two evenings a week from Feb. 15, 1922, to Dec. 15, 1922. In addition to class work the men studied from six to eight hours a week. The ages of students ranged from 25 to 59 years. These men were employed in various foundries. They studied mathematics, science related to metal mixing, shop sketching and blue print reading.

The men appointed a committee to bring in practical problems. Since the instruction was tied in with practical work there was no formal division of subject matter and the progress made was remarkable.

In seventy hours of class room instruction the men proceeded from the addition of fractions to fairly difficult problems in solid geometry. Every topic studied was applied to daily work and therefore frequently involved several subjects. For instance the lessons in arithmetic on specific gravity included the formula for finding the pressure on cores. The uses of chaplets to keep cores in position were considered at this time and the men sketched chaplets and studied the reading of blue prints involving their use.

Carefully prepared lesson outlines providing for individual instruction was one large factor in the success of this class. Another factor was an efficient instructor with industrial experience and a social ideal.

Evening and part-time activities have appealed equally to open shop plants and to labor organizations. The classes taught by foremen in their own shops have proved to be of distinct advantage.

An example of the success of this plan in interesting workers, is found in a class which was organized by the foreman of a metal trades department of a large meat packing plant. Lesson outlines and projects were used in teaching and soon one evening class became two classes, one of which remained in the shop after hours for instruction while the other met before working hours in the morning.

Evening and part-time classes have been organized under this plan in approximately one hundred different subjects and occupational pursuits. One large metal trades plant has demonstrated the practicability of this plan. Foreman training, full time instruction on the job by foremen, evening and part-time instruction both in related subjects and in operations, development and use of a flow chart for workers, formal recognition of the education and training responsibility of every foreman and an honest effort to provide advancement for every worker, are established factors in this plant.

The effect of a wide awake management upon an organization cannot be measured. A management which can plan and install a functioning education and training system can improve operations and processes in many ways. This factory possesses a highly efficient managerial force. While it would be very unfair to point to any improvement in this factory as a result of education and training we may recount the following improvements as among those which have occurred since the installation of instruction:

1—Power costs reduced from $200.00 per horsepower year to $113.15 per horsepower year—yearly saving $60,000.

2—Blast furnace operation costs per ton reduced nearly sixty per cent, total yearly saving approximately $180,000.

Nearly all of this expense for this factory's educational program has been met from public funds which are available for this purpose throughout the United States.

During this period of saving advancement of workers was rapid. This factory is thoroughly committed to education and training as a part of its regular program. Its manager and nearly every foreman realize the need for recognition of production as a social ideal. Skill is produced when and where needed and many of the ordinary labor problems are less difficult to solve. Workers appear happier and more contented than was formerly the case although every other large industry in the immediate community has had serious labor troubles during the past year.

What has been done in this plant by its capable management can be better done in every factory if managements cooperate in training activities.

The immediate struggle between the nations is in the market places of the world. Industrially speaking better skill in production means a better position in the market place. We must increase our skill to keep our position among the industrial nations of the world.

Apprenticeship

By C. M. Morrin, Providence, R. I.

We are here today to discuss the apprentice and apprenticeship systems. Naturally the question comes to mind, "Why?" Isn't it that the employer is facing the very serious problem of securing trained workers? By trained workers I don't mean the specialist or single-operation man; but the man who can carry work through to completion—well trained men who will make the foremen and executives of the future.

Again we ask the question, "Why is there a lack of these trained workers?" To my mind the reason dates back to the introduction of labor-saving machines; and to the development of the modern industrial system. These two changes in the old order of manufacture resulted in a very marked subdivision of labor, and separate operations became almost distinct vocations. The specialist, or one-operation worker, became the man of the hour, resulting in some employers discontinuing all apprentice training.

Apprentice Training Necessary

I hold no brief against the specialist or one-operation man, for I believe that he is needed in the modern system of production. But I do hold that a serious mistake is made when apprentice training is discontinued or allowed to be sidetracked. Of the thousands of manufacturing establishments in the country, how many, I ask you, have apprentice training courses? Yet reports show that about one million young workers are required each year to maintain the ranks of industrial America. The Congressional commission of 1914 reported that hardly one per cent of fourteen and a quarter million workers was adequately trained.

Conditions Responsible for Present Lack of Apprentice Training

Is the employer alone to blame for this condition? By all

means, no; for the labor organizations have and are fostering the spirit that the number of trained journeymen should be restricted. "Why," you ask, "should a labor organization attempt to withold education for workers?" One reason that seems to stand out is that with a limited number of these journeymen, wages would necessarily be higher for that particular trade, so that employers would outbid each other for the limited number of trained men. It has been said that in the city of Chicago a short time ago there was not one apprentice plasterer. The average age of those in the Plasterers' union was between 40 and 45 years. This is an extreme illustration of what restricted apprenticeship can do.

School systems, too, should share some responsibility for this lack of trained workers. Boys have received the impression that theory was all that was necessary to make a success; and manual labor was, to a certain extent, frowned upon. Steps are being taken to remedy this condition through the trade schools and co-operative courses; and I believe that manual training in the schools is a benefit; but does not, and cannot supplant real apprentice training in the shops. Parents are often responsible for preventing boys from entering manual trades by using their influence against it—the belief of the parents being that the boys could do better, to use a shop term, "at a white collar and tie job"—in other words, that a start from the office would be better than from the production department. Possibly the parent often times thinks this from the fact that he himself has made only a partial success because he was not trained; and fails to see the advantages and opportunities for advancement resulting from proper training. These are some of the whyfores of the situation. The next question is, "What can be done?"

What Should Be Done to Attract Apprentices

I believe one of the first things to do is to make our foundry and factory as attractive as possible to our boys in its physical conditions. We should work in close co-operation with our schools; and place before the educators and pupils the possibilities for training and advancement in our plants. In fact, we should place before the general public industrial training in its

true light. In other words, employers should plan an active campaign for industrial training. When I say attractive, I do not mean on paper only. We should institute a campaign for safety; and for the moral upbuilding of all of our employes, for the better our factory and foundry conditions are, the better the grade of workers we can secure.

Active safety work. What has that to do with apprentices? To my mind it is indispensible, for the less hazardous we make our foundry; and the more attention is paid to safety, the more care will be taken; and the easier it will be to interest our boys. The same holds good of orderliness. Well ventilated, orderly foundries make a far more favorable impression, being more conducive to good work and good health, than those of the old order. Adequate facilities for the employes' cleanliness is a condition that affects not only the employes, but those outside your plant will be favorably impressed with the appearance of your employes as they go and come; and the quality of your work may be judged accordingly.

I believe I said moral upbuilding; and I mean by that giving a man the opportunity of making himself self-respecting. Give him an opportunity to learn English if he is not English-speaking. Encourage him to become a citizen, and give him a chance to learn something of our government. Encourage him to save by means of saving plans, insurance, etc. Shop gardens, wherever possible, have a good influence. These are but a few of the ways in which conditions can be improved; and I believe that the lack of these conditions has been the cause of creating the impression that the foundry should be the last place to look for work.

Granted that the conditions in the foundry are good; and that there is an opportunity to secure apprentices, what does the apprenticeship mean? The dictionary says, "one who is bound by indenture to serve some individual or company for a specified time in order to learn some art, trade, profession, manufacture, etc., in which the master or masters become bound to instruct him." That is all very well as far as it goes; and there would be a great improvement over present conditions if even that were lived up to; but the management should not only be bound

to instruct him; but should take an active interest in the apprentice. He should mean more—yes, a great deal more—to the employer than just a boy who is to be a cheap hand. The employer should see to it that the purpose of the training in his factory or foundry is to make a skilled worker; and I want to emphasize *skilled worker,* for I think that we should train the boy to be skilled with his hands primarily; and not attempt to train for leadership if it must be done at the expense of workmanship. Don't misunderstand me and think it is my recommendation to work a man into a narrow groove from which there is no escape. By no means. But it is my belief that skill will develop only by actually doing the various operations; and that repetition makes for skill. As to training for leadership, I believe that leadership is something inherent in the man; and will develop as a man becomes experienced; and that your leaders will stand out and grow to their proper station.

The foregoing is my opinion of conditions as they exist today; and a very brief outline of what can be attempted as a remedy for that which is lacking. I am not here to exploit one system, nor do I say any one system can be used in all cases. However, I do insist that a systematic method should be followed whenever apprentice training is attempted; and that it should be attempted whenever practicable.

Apprentice Courses Should Be Well Organized

Apprentice training is not new with us at the Brown & Sharpe Mfg. Co.'s plant, where it has been a policy to take apprentices during the last 70 years. Our courses include machinists, molders, coremakers, blacksmiths, patternmakers, and draftsmen. We have what we term our apprentice department; that is, our boys, although working in the various production departments, are controlled under one head. A schedule is laid out for each boy and the apprentice department is responsible for his movements from one department or job to another so as to maintain that schedule. This gives a more uniform training; and relieves the production foreman of the responsibility of the boys' training in other departments than his own. But I do not mean that the foremen should be allowed to lose interest in the apprentices There should be full co-operation between

the production foremen and the apprentice department. As I stated previously, our boys are trained under the production departments and under actual production requirements. While this may seem old-fashioned to some, in our experience, at least, it has and is proving better than the segregation plan. Not that I think segregation is not good; but with our conditions, we believe our particular method to be better.

How the Management Keeps in Touch With the Apprentices

In addition to the instruction received from the foremen on the various jobs, we have a shop instructor who visits the boys regularly, giving them advice and instruction about their work. With the regular shop work, we have combined a school course in which we teach elementary arithmetic and applied mechanics—not as academic subjects, but as shop problems, the boys seeming to grasp the ideas better by using applied problems. This school work, we correlate as far as it is feasible with our shop work.

In order that the management may keep a personal interest in, and an acquaintance with the boys, and to have the boys feel that an interest is taken in them, and that they have a chance to bring their particular desires to the attention of those who are in authority, we have a formal system of interviews at stated intervals during the apprenticeship. The boys are interviewed by the apprentice supervisor, the head of the employment department, the works superintendent, the sales manager and the industrial superintendent, almost all of whom are themselves former apprentices. It is proving helpful; and gives an opportunity to draw out the boys and get their reactions from different angles; and gives the heads of the departments a chance of meeting and choosing boys who should prove to be good material.

Advantages of a Trial Period

The fact that we have a trial period before definitely taking on a boy works to advantage both to us and to the boy as it eliminates boys that would be unfit or dissatisfied. This period is for three months, in each of the trades; and if a boy is definitely accepted for apprenticeship, this trial time is included

as part of his total time. We enter into a formal agreement; and require a sum of money to be paid for learning the trades, our reason being that by this method more serious attention is given by both the boy and his parents; and it has a tendency to eliminate the half-hearted applicant. If conditions are such that the entrance fee cannot be paid outright, we arrange for a part payment plan, or we deduct a certain amount from the boy's weekly pay.

To quote from our booklet, "Apprenticeship," the problem of our apprenticeship is to completely educate young men in their chosen trade so that they can qualify with us or elsewhere in the machine industry as highly skilled workmen, and as leaders of those who have not had the advantages of a general training. It is our intention to take only boys who have a sincere desire to learn a trade; and to keep out those who just want a job. A chance applicant from the street, we have found, is not as a rule good material. By bringing the apprenticeship before schools and organizations that would be interested in industrial education, it is possible to secure boys who are really interested and have the ambition necessary to succeed.

Foundry Apprenticeship

That, in a general way, covers our apprentice system; and as you are no doubt, more interested in foundry apprenticeship, I will discuss our course. We try to get boys between 17 and 20 years of age who are of rugged build and without physical handicaps. They must have a grammar school education or its equivalent; and must pass an entrance examination at our school. This examination covers simple arithmetic and such subjects as boys from grammar school should know. If an applicant lives at a distance from our works, arrangements are made with some responsible person in the boys' locality to give him the examination and return it to us. Before the boy begins work he is given a physical examination at our dispensary, and the physician's report of this examination is kept on file with the boy's records.

During the three months' trial period, the boy acts as a molder's helper; and also is given certain routine operations that we may know whether he is fitted for the work or not.

During this trial period, reports are filed by his foremen, shop instructors, and class instructor covering industry, deportment, workmanship, and mechanical judgment. These reports are made on a printed form; and a uniform method of marking is used so that the marks can be averaged to give the boy's rating. If the boy rates a passing mark at the end of his trial period, we arrange to have both him and his parent sign a formal agreement and pay the $25 fee required for learning. This agreement is for a three-year apprenticeship, divided into three periods of 2455 hours each. The time served during the trial period is included in this three-year contract.

The Wage Rate

The wage rates increase at the beginning of each period. If, however, a boy receives an excellent rating in both shop and school, he receives an hourly bonus as long as he holds this excellent rating. Each six months constitutes what we call a term; and the boys' marks are averaged and a report of his progress is sent to his parents or guardian. His school work is carried on during working hours; and the boy is paid for his time. He must spend a definite number of hours at school each week and is expected to turn in a certain amount of work. This work covers arithmetic, foundry problems, and drawing as applied to foundry problems.

The First Year's Work

The whole of the first year is spent in what we term our heavy foundry. Work in this particular section is more general in character and the boy receives a broader training than he would in our light foundry. For the first four months, including his trial period, he acts as a helper to one of the molders. Then as the boy develops, he is placed on what we term the side floor; and is given work to be carried on on his own initiative, of course, under the supervision of the foreman and instructor. After a time on the side floor, he is transferred to the heavy or crane work where he works under a journeyman who assigns work to him that gives him a general training.

The Second Year

The first three months of the second year are given over

to coremaking. Here again, the boy is put under the direct supervision of a journeyman coremaker; and works somewhat in the nature of a helper. After finishing this work he goes to our light core room where he is put on work that he can carry through by himself. For the remaining nine months of his second year he again returns to the foundry where his work is carried on by himself. This work is of a more general character; and is given with a thought of creating self-confidence and to develop his reasoning power.

The Third Year

The first three months of the boy's third and last year are spent in the light foundry on the bench, usually beside a molder who is picked out for his thorough workmanship and ability to handle boys. He receives instruction from this journeyman as well as from the foreman. The next two months he spends on molding machines going through the regular routine work of these machines. He again returns to the heavy foundry and is expected to carry on work of a light character entirely on his own initiative under the supervision of the foreman. After five months of this heavy foundry work, he goes to the cupola for a month, where he is taught charging, pouring mixtures, and work of a like nature in connection with the cupola. The boy's last month is spent in the heavy foundry work of a general character with the thought of bringing him along into work that would be suitable for him after his time is completed.

Apprenticeship for Coremakers

Our coremaker apprenticeship covers a period of 1½ years, divided into periods of six months each. Of the first twelve weeks, or trial period, half the time is spent in the light core department on bench work, and half the time in the heavy core department on floor work. The remaining twelve weeks, if the boy has proven satisfactory, is spent in the heavy core department.

The second six months is spent entirely in the light core department. The last six months the boy is returned to the heavy core department and finishes his time there. As in our other courses, the coremaker has a school course of his

own; and must attend school at stated periods. He also receives instruction by means of lectures.

Conclusions

In conclusion let me say that we do not insist that ours is the only one system; neither do we say that any one system can be universally used. But we do believe that you must have some sort of a definite system to make a successful apprentice course. We believe that if the responsibility for training the boys is not centralized; and if you resort to a haphazard method of moving the boys from job to job, your aim will not be accomplished. Neither will an apprentice system be successful without full co-operation from the heads of the plant to your subforemen and straw bosses.

We believe that better results would be obtained if there were closer co-operation between schools and factories; but I do not believe that school courses whether manual training or trade schools, can supplant apprentice training in the schools or factories. We believe that under our conditions a formal agreement works to advantage both to the employer and to the employe; and we believe that a foundry apprenticeship, to be successful, should cover all branches of foundry work.

Training Foundry Apprentices at the Falk Corporation

By H. A. Frommelt, Milwaukee, Wis.

No one who has passed through the past decade or two of our industrial history needs be reminded of the tragic situation that exists as regards the lack of skilled craftsmen in the metal trade industries. The war, quite naturally, accentuated this lack, and now after two years of business depression, when we are again on the up grade, it is more than ever apparent that our productive capacity is seriously curtailed owing to a lack of skilled productive help. All this you, as well as we farther to your west, realize and appreciate.

There is no question then of the need of a training program designed to furnish this skilled productive help. There may, however, be some question with regard to the nature of this training program, especially the length of time. It might be well at this point, therefore, to say just a few words in this regard.

There seems to be a tendency in more than one quarter to rely on a period of training less than the old traditional four year standard. Here and there vestibule schools, training quarters and specialized educational departments have been installed with an attempt to turn out a sort of hot-house product. But we are only intriguing ourselves into believing that such products are suited to our needs. Two year apprenticeships are also being tried in the hope that this will provide a remedy.

The ideas back of this specialized program need only to be examined briefly to discover their fundamental weakness. The arguments used as a basis for these training programs run something as follows:

The newer methods of education, text books, close supervision and up-to-date physical equipment make it possible to

train men much more rapidly than in the old days when these were lacking. That this is but a half truth becomes apparent immediately if we stop to consider how much more the craftsman of today need know to become skilled than the craftsman of old. How much, for example, has the whole science and art of the metallurgy of iron and steel, their heat treatments, and alloy making, grown in the last decade? How much of this should a good craftsman in the steel industry know and appreciate to become thoroughly skilled? True, there are not many at the present time among the few remaining skilled mechanics who do know and appreciate these things, but. if the foundry art is to keep step with the other departments of our manufacturing industries, it is certainly true that each craftsman in this department should, and must know, and appreciate besides, the new developments in the science of metals. Unless they do, we certainly cannot hope to draw from among their number men who can act in an executive capacity.

Four Years Necessary to Train Adequately

Now, if we are to train men who are thoroughly capable in the art, considered as a whole, it is surely obvious that we must train them for at least four years. It is true that we can take the average individual during his learning years and teach him to make a certain mold or class of molds within six months or a year, or thereabouts. But to take the same individual and give him such a training that he knows not only how to ram the sand around his pattern, but also knows and appreciates the materials he is handling—sand, steel, etc; it certainly is patent that four years is only too short a time. Anything less than this becomes a training program not for full fledged, honest-to-goodness, all-around mechanics, but simply specialists in this or that small department of the foundry.

Let us consider then for the moment, if this point has been sufficiently touched upon at this time, the elements essential to the success of an adequate apprenticeship.

Essentials Necessary to Successful Training

I have seen fit to group these elements under three distinct heads, which run about as follows:

First—It is necessary to have a plant and a product of such quality that pride of craftsmanship can be taken in them.

Second—It is necessary to have capable general and departmental executive organizations.

Third—It is necessary to have an adequate apprentice or training organization and program.

To elaborate briefly, it is clear upon a little consideration that it is futile to consider a training program of the kind we have in mind unless the product, and the plant making the product, are of such nature that the workers themselves can find that satisfaction in the work, which is of necessity a characteristic of the true craftsman. Not only must the product be sufficiently varied, but the quality of workmanship demanded must be such that it will not violate the true ideals of craftsmanship.

It follows from this quite readily that a second very necessary characteristic is capable general and departmental executive direction. An organization of this kind must thoroughly appreciate the necessity of a training program. If the executives were solely imbued with the idea of production and production only, and were incapable of appreciating the equal necessity of craftsmanship for that production, training programs would be of short life in an organization of this kind. From this second necessary characteristic follows the third, quite obvious also.

There must exist an apprentice or training organization in this ideal plant, which we are considering, that will be of equal importance with the production phase of the business. This apprentice organization must be thoroughly capable of training a sufficient number of men as craftsmen in the various trades of the plant. These three factors must, under ideal conditions, interact noiselessly and smoothly. If they do, production, which is the ultimate aim of any manufacturing business, will go on uninterruptedly, never experiencing a dearth of competent craftsmen.

Classification of Apprentices

These ideas have served as a basis for the training program put into effect in the plant of the Falk corporation. We have, as most of you know, a more or less general manufactur-

ing engineering business, specializing, however, in helical gears and railroad castings. We employ mechanics in the machine, foundry and pattern departments. It was necessary, therefore, in instituting a training program to make it sufficiently broad to cover these essential trades. The program, however, has been extended sufficiently to cover five essential divisions, and two auxiliary branches or divisions. Without commenting in detail on this point, let us start by saying that we group all of these trades under the general title of "Engineering Trades." The five divisions run as follows:

Machine Division, Steel Division,
Pattern Division, Design Division,
and Operating Division.

In addition to this, apprentices are employed in small numbers in the electrical and sheet metal departments.

It might be well at this point to explain reasons for this particular classifaction. As all of us who have experience in foundry work, know there is a deep traditional feeling existing in opposition to the molding trade. It probably comes to us from the days when each molder in special shoes and with his legs swathed in gunny sacks, poured his own metal. The dangers involved gave rise to a feeling of hatred against anything that had to do with molding. This even took hold of our educational system and of the medical profession to such an extent that our educators treat with silent contempt the entire basic industry of iron and steel, and many of our doctors are only too ready to help the exodus of mechanics from the foundry with a certificate of illness due to alleged injurious effects of foundry air and surroundings.

Considering all this, we came to the conclusion that it was better to combat this, partially at least, and for the time being, by giving the whole foundry business a new label. This was done by regrouping all the metal trades under the general heading of "Engineering Trades" as indicated above, and the foundry then comes under the steel division. (In the case of a gray iron foundry, the classification would probably be "iron division.")

Schedule of Work Outlined

Referring to the five main branches enumerated above, it should be remarked here that a definite schedule of work has been laid out under each. Thus, the machine division includes machine and bench work, erecting shop work and in some cases, special work, such as heat treating and machine estimating. These divisions are not hard and fast. Thus a young man who shows particular adaptibilities will be given suitable experience. As an illustration, a young man who had finished a four-year apprenticeship in the machine shop, and who had asked voluntarily for one year additional in the foundry, was after that sent to a local heat treating company for that experience, and then finally to the Warner & Swasey company of Cleveland, Ohio, for a six months' special course in machine estimating, lay-out, and set-up. He has now completed this special course and is returning to us on the first of next month. He will be used as an instructor over the screw machine department. We mention this here, merely to emphasize the point that the divisions referred to under each of the major trades, admit of considerable change and adjustment to suit the needs of the individual as well as those in our own plant.

Coming more specifically now to the steel division, we have in general five divisions—molding, core making, heat treating, furnace milling and steel testing, inspection, etc. Each young man indentured in the steel division will normally pass through these five branches. Here and there a young man may be sent to a gray iron foundry for cupola experience, or to a gray iron foundry for experience in iron castings.

The pattern division is obvious, without further explanation, particularly as there are no definite branch divisions. A design division, however, consists of one year of shop work, either machine or foundry, or both, and two years of apprenticeship in the drafting and design department. The operating division includes three years definite training; one of which is given over to machine shop work, the remaining two to experience in both the boiler and engine rooms of the power plant.

Class Instruction

But this is not all. There is in addition to the definite schedules of work laid out in the shop, an equally definite schedule of school work laid out, which, as will be seen later, is designed to supplement the actual work in the various departments. Wisconsin's apprenticeship law requires a certain amount of school work under prescribed supervision; in our case, in continuation schools. It was felt as soon as we had entered upon this training program that some of this school work should be undertaken by the company itself. The close contact thus established between the apprentice boys and the company apprentice organization was felt to be of so much value that it could scarcely be sacrificed even at the cost of an additional hour or two of school time. Subsequent results have proven the validity of this supposition. There is thus established a close and intimate contact with each individual apprentice, such that enables the company to maintain a well knit and well organized apprentice group.

Among ourselves we refer to this school training as "Related Shop Technique." The idea, we believe, is thus quite well expressed, namely, that the technical information given to the boys is such as is necessary for the work that they are actually doing in the shop.

We have established connections with the Continuation School in such manner that the work given in the company class room is merely supplementary to that given by the Continuation School itself and taken as a whole presents a well formed program. Thus there is no overlapping nor reduplication.

Referring specifically to the program laid out for the apprentice in the steel division, it may be of interest to know that the school work comprises instruction in the mathematics required for a good craftsman in that division in blue print reading in shop sketching, in the metallurgy of the materials that they are handling, the composition of the sand, and other molding materials, and the technical data that are necessary for manual operations in the actual molding work.

It is thus seen that this complete training program, con-

sisting of the work in the shop and in the class room, is such as to train fully equipped mechanics. In addition to the program of school training laid out in conjunction with the Continuation School, this company has entered into an agreement with the International Correspondence Schools whereby a number of apprentices are enrolled with this school in courses adapted to their special needs. The time for study is given by the company, amounting to five hours per week, with private instruction and help from the apprentice organization. Entirely special courses are occasionally laid out, such as, for example, a production course for young men who are likely to be used later on as foremen or executives. Here again an attempt is made to keep the whole program as elastic as is necessary for individual needs rather than to make it a series of cast iron compartments into which individuals are squeezed.

Four years is, if anything, entirely too short for this program. It is sufficiently comprehensive, we believe, to produce well trained mechanics from among whose numbers we can chose men competent as foremen and executives. In addition to this it is obvious that it will provide an entirely sufficient number of well trained mechanics.

Schedule of Rates

To come to more definite details, it may be of interest to refer to the schedule of rates and grades of apprenticeship in each department. The basic apprenticeship consists of four years in all departments. Credit, however, is given for any school work over and above the grade school. Thus one year credit is given to a high school graduate, making his apprenticeship three years. An additional year is given to a university graduate, making his apprenticeship two years. The vast majority of apprentices, however, are indentured at the age of 16, the minimum age in Wisconsin. It would only seem quite fair and just to a young man four years older, and who had four years of training given in a high school, to credit him with at least one year on his apprenticeship.

These, in the main, constitute the principal grades of apprenticeship in these departments. The rate for the regular four-year apprenticeship is indirectly set by the industrial

commission. In Wisconsin the machinist and patternmaker apprentice rates start at 18 cents an hour. In the foundry the grade school apprentice starts at a rate 25 per cent higher. This has been set and agreed to by the local metal trades, and then sanctioned by the industrial commission. The high school rate begins at 35 cents and increases every six months during the three years by 2 cents increments. The university rates begin at 45 cents and increase every six months up to 55c at the last six months of a two-year period.

These rates are more or less uniform throughout the entire Milwaukee metal trade district.

It may be well to emphasize again that the various divisions as regards schedule of work referred to above, are not necessarily inflexible, but admit of even considerable change as circumstances demand. In other words, the idea is not to make a young man fit into a definite compartment or division, but rather to make the experience suit his particular needs and legitimate desires.

While no program of this sort can be said to be definitely and finally successful unless it has graduated trained mechanics who have remained with the organization, yet we have gone on sufficiently to be able to warrant our belief that the essentials of the program are fundamentally correct. We have at the present time about 110 apprentices among a total number of employed of about 1200. There are about 40 apprentices in the various grades mentioned above in the foundry.

Factors Which Have Made Training a Success

The factors which have tended to make a success of this program might be considered under eight different heads; the first of these, and probably the foremost, is proper apprentice supervision. This must be embodied in a man who has had sufficient background, along with technical and practical training, to lay out a well co-ordinated program, not only in the shop, but in the class room as well. It is necessary, of course, that he be able to adapt himself to the existing organization without causing undue friction, and also that he have no little insight into the character and even eccentricities of youth.

The second essential factor follows directly from this, namely, close supervision by a person in the organization not responsible for production. The apprentice department must never be hampered with the demands of production. It must be entirely free to play its own game within reason over and above the production side of the business.

In the third place must be mentioned the close co-operation that must exist between the parents and the apprentice organization, and through it with the company. Modern industry with its mammoth plants and large organizations has built by its very nature an invisible barrier around itself, separating it effectively from the hearts and the homes of the men who make up its human element. And yet, there is nothing so essential to the success of apprenticeship as close co-operation between parents and the company. Both must be vitally interested in the training of the boy, and yet how can this be possible unless some special means are taken to break down the barrier that exists.

The apprentice organization must take upon itself the task of gaining the sympathies and interests of the parents in this problem, and to accomplish this in our case we have seen fit to devote a large portion of our time to visiting parents, inviting them to visit the plant, and to establish a monthly connection through records of their son's progress in shop and school. This, we believe, should be emphasized as making up one of the largest factors in the success in this program.

As the fourth essential factor, let us put down the necessity for definite records. By this we mean, such records of shop and school work as will enable the apprentice organization to shift apprentices from one class of work to another at the proper time, to grade their shop and school work for purpose of classification and reference, and finally for such records as will be necessary later in making up a report of a man's fitness for a certain job.

In the fifth place it is necessary to emphasize the necessity for an adequate training program in each department. The foundry training program should be of such nature and so presented to the prospective apprentices that they will see the

immensely interesting future that lies ahead of them. This is in addition, of course, to the demands coming from the needs of properly trained men.

The principle of reward should also be recognized, we feel, as an essential factor in any training program. By this is meant a system of awards or prizes set up in each department, which will put the various classes of apprentices in competion one with the other, and thus bring out their very best efforts individually. This was done in each department in our plant. Three prizes; first, second and third, in addition to a general plant prize to which all were eligible, were set up.

If apprenticeship is to be successful in an entire district, not only in isolated plants, a real spirit of co-operation must exist between the various plants in that group. It is obvious however, that the smaller plants will be unable to pursue a training program such as has been here outlined. For this reason the member plants of the Milwaukee metal trades group have combined in such manner for the purpose of such training, that the smaller plants, machine shops, foundries, etc., can send their apprentices to the larger plants to complete their training and have the advantage that a comprehensive shop and school course, such as the smaller plant would find uneconomical. This is an actual operation, and we believe has proved itself an essential factor in the success of apprenticeship in this district.

As a final factor, which is really corollary to the one last mentioned, it has now become obvious, undoubtedly, that a training program, if it be successful at all, must be sufficiently comprehensive to invision the needs, not only of an individual plant, but of an entire district. To accomplish this the member plants must enter into a whole-hearted spirit of co-operation and have faith in one another to the end that they are willing to exchange apprentices, training and experience.

It is essential that we comprehend fully that foundry apprenticeship is not only possible, but can be made decidedly successful, providing only we realize the difference between the industries of today and those of old and are willing to adapt our training programs to the changed conditions. We can se-

cure for indenture sufficient young men for our needs. It is frequently said that the young men of today are different from those of an earlier generation. This is probably true, in the accidental characteristics at least, but fundamentally they are just the same, and if we can duplicate the apprenticeship of 50 years ago, when the master was president, general manager, foreman and craftsman, and bring the same intimate relationship to bear between the company and the young learner as in those days, in addition to providing him with an actually adequate opportunity for learing the trade, we shall have no trouble in making this apprenticeship thoroughly successful.

Apprenticeship in the Foundry

By J. R. TANNER, Pittsburgh

It is not the intention of the writer of this paper to present a treatise on the art of making mechanics in the foundry but only to outline a very few points which in the training system of one foundry, are helping to the desired end.

Our system does not include a formal contract but is based upon a mutual agreement, verbal on the part of the apprentice and also on the part of the company, but in the latter case with the understanding that the course will cover certain specified periods in different branches of the trade. A written schedule of the course is given each boy when he enters our employ.

For many years a formal contract was entered into, but we found that if a boy decided to quit and could not be influenced to complete his course the advisable procedure was to allow him to quit as nothing could be accomplished through compulsion.

At the end of each of eight periods each apprentice is credited with a bonus of $50.00 payable when he completes his course but forfeited if he quits before doing so.

The course is quite simple and is designed to enable the apprentice to learn to make castings. Educational features are at a minimum and on this ground we might be criticised but we believe that advancement will not be hindered for the mechanic who knows his trade for the qualities for leadership are innate. Some of our best foremen are our own product and on the other hand no amount of study could have developed those not so endowed.

Our periods of training are as follows:

1.	Small core room	4 months
2.	Large core room	4 months
3.	Molding	36 months
4.	Engineering department	2 months
5.	With cupola man, forenoon On charging floor, afternoon	1 month

6. Weighing iron, forenoon }
   With cupola man, afternoon }
   ..... 1 month

The only feature outside of trade operation is the two months toward the end of the course spent in the engineering department and though the work there familiarizes the apprentice with reading drawings and making sketches that is not the primary idea, for even if he never sees another drawing his daily contact with the men of the office goes far to remove the prejudice against office men so strong among many mechanics.

No apprentice system will run itself. There must be some one to follow the movements of the boys already taking the work and to persuade new boys to start and the last is the most difficult to accomplish. It is hard to persuade the average boy to go into the foundry. This has been said so many times that many believe it impossible, but even though difficult a degree of success can be attained by the man who is not disheartened by many failures, who takes advantage of all the assistance available, particularly acquaintanceship with his own molders and the earnest work of those in charge of our industrial schools.

There is no one who will not agree that the replenishment of our supply of skilled men is vital to our industries and even though the foundry presents one of the hardest problems it is not incapable of solution and the answer is less lamentation over the diminishing supply of mechanics and more painstaking interest and hard work.

By What Process Shall the Foundry Industry Maintain its Rightful Proportion of Brains and Skill Among Industries

By A. L. Williston, Boston, Mass.

A number of weeks ago I received a very cordial invitation from your papers committee, to prepare an address to be read before this association at its meeting today, making definite and concrete recommendations as to the ways in which the American Foundrymen's association could advance the subject of training foundry workers, and especially how they could best co-operate with an institution like Wentworth Institute of Boston—the institution of which I have had the honor to have charge since it was first organized twelve years ago.

It is certainly not necessary to take your time to dwell on the rate at which changes in the foundry industry have taken place and the changes that are at the present moment in process. You are studying these matters and are intimately familiar with them. Yet it is true that it is extraordinarily difficult for persons—especially oftentimes for those who are extremely close to certain problems—to visualize the magnitude and the significance of the changes that are taking place in their very midst. We are constantly hearing statements of one kind or another that are intended to bring home to us the extent of the changes which are today being caused by the increasing use of applied science methods in production, but I find that as I talk with large manufacturers that many of them fail to understand the measures they must take in order to keep pace.

Last fall Edward A. Johnson, head of the foundry department at Wentworth institute, sent out a very large number of inquiries and conducted an extensive correspondence with many of the leading foundries in the United States to find

out what they were doing in this direction and the extent to which they were prepared to give active co-operation to a progressive program for training foundry workers and leaders. The replies showed keen interest in many directions, but on the whole were extraordinarily disappointing.

As I reviewed this correspondence with Mr. Johnson, I was amazed to find in how many instances firms of importance doing a large annual business and with heavy investment at stake were doing nothing or waiting quiescently for some plan to be suggested, or were relying on some antiquated or totally inadequate system of apprenticeship which would hardly have been sufficient for an organization of one-fifth the size twenty-five or thirty years ago. Others were relying on co-operation with school efforts, in manual training schools, or in continuation schools, or in other elementary industrial schools that again were equally inadequate. Admirable as these elementary beginnings may be, it must be plain that they constituted but the "teaching of an alphabet" and are not to be relied on for your purposes unless they are supplemented by a much more far-reaching elaborate program of training.

Of course, in this mass of correspondence to which I have referred. there were striking exceptions, but these exceptions, it seemed to me, were so few and far between as to be "but the exceptions to prove the rule" that the great foundry industry of America is far behind many other industries in its training opportunities.

All of you are familiar, I suppose, with what the Wilson Foundry Company of Pontiac, Michigan, for example, is doing in these directions. Why are not hundreds and hundreds of other foundries getting corresponding results and using corresponding methods? The answer is, it seems to me, that there are not enough young men coming forward with the combined skill and technical training that is essential.

Present-day standards in the foundry industry call for more than an acquaintanceship with a heap of sand, a shovel, and a rammer. Modern foundry practice requires men who not only have a wide range of practical skill, but in addition

have a store of technical and scientific knowledge to enable them to cope with the new kinds of problems and constantly changing conditions. The development of machine and rapid production methods requires an ability in reasoning, and an imagination in planning, essentially in line with the engineering spirit. And for leadership in such work, breadth of view, resourcefulness, and originality, too, must be developed.

It surely is obvious that the ordinary foundry apprenticeship provides very little, if any, of this sort of training. Probably in at least 19 out of 20 of the shops where the term "apprenticeship" today is being used, nothing much beyond the *elementary acquaintanceship with the heap of sand, the shovel and the rammer* is being attempted.

Foundrymen are agreed that it is difficult to interest the right kind of young men in foundry work today; and some are inclined to blame the boys of the present generation rather than the conditions in their own plants. Ask them if they have ever tried to give boys the opportunity easily and surely to get true insight into all the fascinating intricacies of the applied science problems that are interwoven all through the foundry industry or to draw for them the fascinating picture of progress and achievement that lies open! How many foundries, frankly, can do this? Here and there, perhaps, there is an exceptional instance; but in the main, is it not plain that your industry must rely on its ability to develop a co-operation with organizations and institutions that through long experience have made this their business, and have learned to present practical work to boys in just this attractive and efficient way?

The average American boy is of the same type as the boy of years ago. He is just as ambitious to learn and to grow, as was the boy of previous generations. He has just as much courage and promise of accomplishment, but he will not accept work in any line in which he cannot see some outlook, and some possibilities for his future well-being. The foundry industry at the present time has extraordinary opportunities for the boy who can be properly trained and prepared to grasp them; but without systematic and organized training his chances of

promotion to the better grades of positions are exceedingly small. He can see this intuitively, and hence he shuns work in your industry.

Trade and technical schools of the better sort like, for example, the Wentworth institute with which I have been connected, working in co-operation with industrial associations, can attract the best of boys and can develop in them grades of intelligence and initiative and qualities of industry and loyalty; that no commercial plant can hope to approach.

Foundry Training at Wentworth Institute

I have just referred to Wentworth institute, and it may not be inappropriate for me to take just a moment to tell you a little of its work. They have in all about 50 different courses in their day and evening schools. But it is only the courses in foundry practice and foundry management in which you are interested. They have a nine months' course in foundry practice in which a young man spends eight hours a day—one-half of his time in the shop—the other half in mechanical drawing, practical mathematics, foundry chemistry, strength of materials and other applied sciences. He is working continuously in competition with other young men who are ambitious, and unconsciously he is cultivating the habit of trying to excel in all that he does with his hands, and at the same time of trying rightly to understand the reason for everything that he does.

They have, too, a longer and more advanced course for young men of exceptional abilities to prepare them for foundry management. This course includes two years of added training in shop practice and shop management, and in more advanced applied sciences; and permits time for the study of cupola practice and scientific control of all foundry processes. It is a course that I think has no duplicate in America, and it is a course that every member of this association should be familiar with.

In addition there are evening courses in foundry practice; in elementary foundry chemistry; in advanced foundry chemistry; and in metallography applied to the foundry industry. All

of these courses, day and evening, represent an evolution, and a combined experience. Mr. Johnson, the head of the department, to whom I have referred to before, after years of practical experience and technical training, has for twenty-three years been developing his teaching methods, first at the University of Minnesota; then at the Winona Technical institute, Indianapolis; and for twelve years at Wentworth institute in Boston. All of this has been constantly supplemented by his staff of loyal assistants.

I have suggested in the title of this article that there is great likelihood that other industries will secure a leadership in this particular at the expense of the foundry industry.

It seems to me that this is true. If you gentlemen were familiar with what the printing and the graphic arts associations of America have been doing for nearly a generation, officially through their associations, and if you knew the sums of money that these organizations and this industry have been spending for this purpose, you would feel with me that this danger was real. A similar statement might be made regarding the electrical industries, the cement industries, and the harvester and agricultural machinery industries, or in fact regarding several other groups of industries.

Training Problems Reviewed

First, I wish to refer to a convention that was held in Boston on April 7 of this year.

This convention was an illustration of a way in which an association like yours can direct public attention and secure public interest in an educational program such as I am recommending. The Associated Industries of Massachusetts in cooperation with societies and other educational agencies directly interested in technical education held this convention on the subject of "Industry and Education" and stated that the purpose of the convention was to focus attention on problems which both industry and education were jointly facing. They secured speakers like Charles R. Gow, president of the Associated Industries of Massachusetts; Everett Morss, president Simplex Wire & Cable Company; George W. Coleman, presi-

dent, Babson's institute, on the one hand; and men like Dr. Charles W. Eliot, President Emeritus, Harvard university, Henry W. Holmes, dean, Graduate School of Education at Harvard university, Dr. Charles R. Mann, director of the American Council of Education at Washington, and Dr. Payson Smith, commissioner of education for Massachusetts.

These men and others like them came together with representatives of industry and representatives of educational institutions to seriously consider ways and means for their joint action.

Dr. Smith, representing the State of Massachusetts, spoke earnestly on the need of an increased co-operation between industry and education. Mr. Gow, president of the Associated Industries, described the extraordinary rate at which changes in our industrial affairs were taking place, and stated that we have come to a point in industry where industry not merely needs education—"it is a necessity." He also earnestly stressed the responsibility of the manufacturer for doing his part in developing *brains*.

Dr. Charles W. Eliot, followed Mr. Gow's thought, speaking on the topic of "The Larger Responsibilities of Education," especially in directing youth to occupations for which they have natural apitude.

George W. Coleman, spoke on the conviction which his institution held that we were facing a new order in both business and industry, and especially the industry must do its share for the benefit of those who are attracted into its ranks, provided it wishes to survive.

In conclusion Robert O. Small, Director of Vocational Education for Massachusetts, described the existing school agencies in evening schools, in continuation schools, and in day trade schools —public and private; and made an earnest plea for the co-operation of business and industry in co-operating for the extension and development of such trained agencies, stating:

"Business should be willing to join in this program for the education of our youth's and their adjustment into participation in the world's work. Business concerns write off annually, large

amounts for replacement of their machinery. Only with their "human resources" does business pursue a policy of using up rather than recreating. Through co-operation with established school authorities, public and private, in programs of part-time education, business can profitably apply to their human resources the principle long in effect with their material resources.

"Mr. Employer, this is as much your responsibility as it is the schoolmaster's. The call to service is written solemnly for you both."

Gentlemen, when a group of men of such reputation give their time to the consideration of such topics, it seems to me that it is worth while for us to give serious heed to their words.

Recommendations to A. F. A.

We have certain recommendations to make to your association and these recommendations are:

First: That you endeavor in every possible way following the Associated Industries of Massachusetts to waken public interest in the need for education, especially in the foundry industry.

Second: We recommend that you at once appoint a strong and active committee on education and training for the foundry industry, made up of men of action, with a secretary, and a sufficient appropriation of money to enable it to function efficiently.

Third: We recommend that you at once pass resolutions officially endorsing as an association all schools that have special courses, having for their principle aim the training of foundry workers or "foundry leaders," provided these schools meet the approval of a committee that you may designate or appoint, as to quality of instruction, as to equipment, and as to staff of trained and experienced teachers.

Fourth: We recommend that you demonstrate that your desire for co-operation is sincere and genuine by establishing in such schools as you may endorse from time to time, from two to four scholarships of from $200 to $250 each, for boys of exceptional ability or promise.

Fifth: We recommend that through an active committee on education you endeavor to persuade local associations and prominent members of your association to offer similar scholarships to such schools.

Sixth: We recommend that through such a committee on education you endeavor to enlist the active support of as many members as possible in properly advertising and making known the good work of such schools as upon proper investigation are found to be spending efficiently thousands of dollars for the purpose of training young men for your industry.

Seventh: We recommend that through your committee on education you similarly interest members of your association in endeavoring to send to such schools promising young men for training.

Eighth: We recommend that through your committee on education you similarly interest the members of your association in finding suitable openings in their plants for persons who have been trained, and also that your members be urged to create proper avenues of promotion for them.

Ninth: We recommend that through your committee on education you enlist the interest of all the members of your association in making it clearly known throughout their plants and to all persons who apply for work, that you prefer to employ persons who have proper training as a background; that you desire in your organizations persons who through night schools or other ways are continuing to obtain training; that your industry offers positions of promise; and that in the long run you are willing to pay for brains and ability.

In conclusion, may I say that if every foundry in the United States would cultivate the habit of seriously asking the question of every applicant who applies at the employment door for a job "Have you ever had any trade or technical training?" and of regularly stating "That the firm prefers men who have made a serious effort to make themselves competent and efficient," I feel sure the situation would surprisingly change within a decade.

Applied Photomicrography of Foundry Sands

By H. W. Dietert, Urbana, Ill.

Photomicrography furnishes an excellent means of research and by means of filing the micrographs, a permanent record is obtained. It is predicted that eventually the foundry industry will use microscopic examination for research purposes to an extent equal to that of other metallurgical industries.

The use of the microscope for visual examination of the sand and of a micro-camera to take micrographs will prove one of the greatest educational factors to the foundrymen, because this equipment will quickly reveal to the trained eye the factors that determine the permeability, bond, and nature of casting surface of a particular sand. The microscope shows why certain properties make a sand suitable for molding purposes.

The most important factors that determine the permeability, bond and nature of casting surface produced are, namely; shape of sand grains, fineness, proportioning of the grain sizes, clay distribution, completeness of clay coating around each sand grain, quality of clay coating, the water content, and the amount of impurities contained in the sand. In this paper it is desired to show how to determine these properties of a molding sand by the use of a microscope and also how to best illuminate the sand for the different determinations.

The equipment selected for microscopic examination and making photomicrographs of sands should be adapted to low-magnifying field work. To avoid difficulties as uneven illumination, puzzling colors, and optical difficulty of focusing at once on the various planes of a conical sand grain, a study should be made of the component parts of the photomicrographic equipment, such as microscope, lenses, illuminating system and camera.

Fig. 1 shows a serviceable photomicrographic equipment used both for visual examination and for photomicrographing foundry sands in the Foundry Laboratory of the University of Illinois.

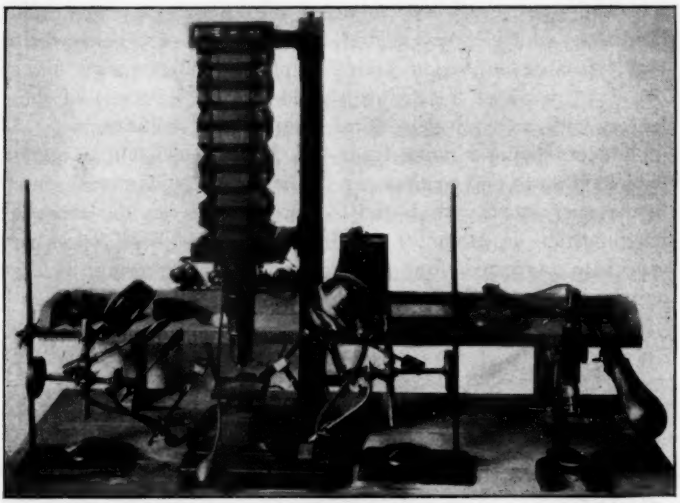

FIG. 1—PHOTOMICROGRAPHIC SET-UP WITH CAMERA FITTED WITH A RACK AND PINION FOCUSING MOUNT. THE MICROSCOPE ON THE RIGHT IS ALWAYS AVAILABLE FOR VISUAL EXAMINATION. A MICROGRAPH THREE TIMES AS LARGE CAN BE PHOTOGRAPHED WITH CAMERA FITTED AS SHOWN THAN IS POSSIBLE IF MICROSCOPE IS ATTACHED TO CAMERA

Microscope

The microscope shown in the right-hand portion of Fig. 1 is a simple compound microscope equipped with a fitting to take a sub-stage condenser, a compact set of optical lenses that collect light rays and direct them on the sand sample from the bottom.

Lenses

Only a few lenses are needed, but they should be of the best quality and suitable to this field of investigation. The eye-pieces of greatest value are the 10 and the 5 power, either

of which may be inserted in the top telescoping tube of the microscope. The lenses that screw into the lower end of the body tube of the microscope are called the objectives. The objectives of 16 millimeters and 4 millimeters focal length give a range of magnification from 50 to 430 diameters when used with the above eye-pieces. One of the low-power photographic objectives which is best suited for this field may be used for both visual examination and for photographic work. Every one doing work of this nature should have at least one of these lenses, with an equivalent focal length of 42 millimeters or 32 millimeters giving a range from 4 to 24 diameters with a camera extension up to 640 centimeters. When the 32 millimeter is used in the microscope with 5 to 10 power eye-pieces, the range of magnification is from 20 to 40 diameters. These lenses are especially corrected for photographic work, covering a large angular field and have a considerable depth of focus.

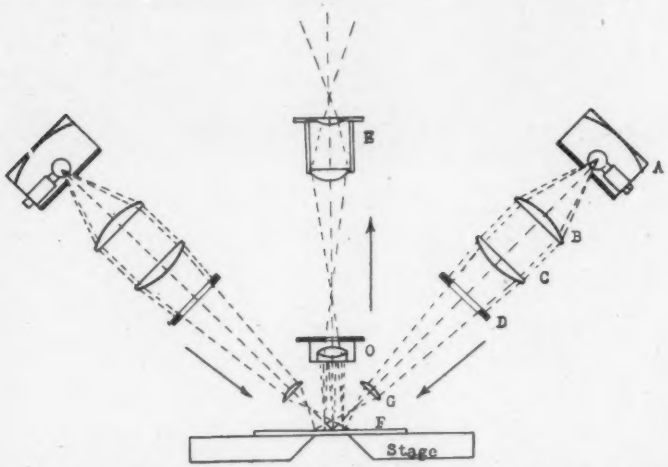

FIG. 2—DIAGRAM SHOWING THE PATH OF LIGHT RAYS WHEN USING TWO RADIANTS FOR REFLECTED OBLIQUE ILLUMINATION

Micro-camera

The microscope is used only for visual examination, while the micro-camera is used for taking micrographs up to 24

diameters. In case micrographs of clay of higher magnification are desired the microscope is placed under the camera. It has been found desirable to enlarge micrographs of sand to get magnifications of about 24 diameters. The set-up as shown in Fig. 1 has proved the most satisfactory to the writer, for the microscope is always available for visual examination and the camera set-up is never disturbed. A still greater advantage is that the micro-camera equipped with the rack and pinion focusing mount will take a photograph three times as great in area than when the microscope is attached to the camera, for then there is the light interference of the microscope tube. The camera shown is a Bausch and Lomb 4-inch x 5-inch Type H camera equipped with automatic shutter and a rack and pinion mount, seen projecting down from the camera. The photographic objective lens is screwed into the bottom end of this mount, and is focused by racking the telescoping tube up or down by means of a rack and pinion included in the mount.

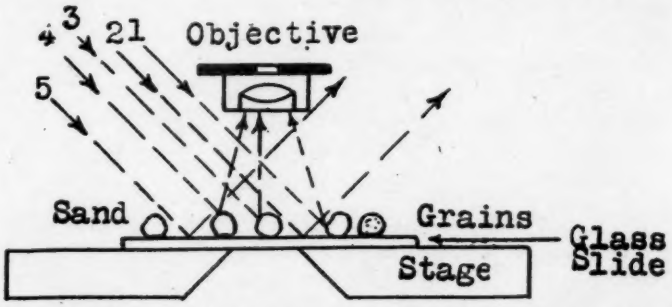

FIG. 3—DIAGRAM SHOWING THE PATH OF LIGHT RAYS WHEN USING GLASS SLIDE TO GIVE DARK BACKGROUND IN REFLECTED OBLIQUE ILLUMINATION

The slide with the sample of sand to be photographed, is placed on the stage just beneath the objective lens.

Illumination

The illuminating system as shown in Fig. 1, consists of two 6-volt, 40-watt tungsten lamps with concentrated filament. The current is supplied from a 110-volt alternating current circuit and is stepped down to 6 volts by a 100-watt multi-volt trans-

former. The optical part of the system consists of a combination of plano-convex lenses and a small plano-convex lens to project the light rays on the object. The intensity of either light may be changed by decreasing the voltage on that particular lamp, thus producing any degree of shadow if such is desired. The two separate lamps form a very complete illuminating system for top illumination, but good results may be obtained with one light source by using a V bent piece of cardboard as a reflector on the stage. When using a single light source, the radiant should be so placed that light rays will impinge on sand in a more vertical angle. To illuminate the sand sample from the bottom, a sub-stage condenser is used, but as it is located beneath the stage, it is not visible in Fig. 1. A sub-stage condenser is nothing more than two or more lenses mounted in a cylindrical retainer, and it is used to collect and direct light rays just as the lenses do in the top illuminating system, with the exception of directing the light vertically upward. The light source for the sub-stage condenser is obtained from a small 110-volt sub-stage lamp as shown beneath the stage of camera set-up. The top lens of the sub-stage condenser was removed so as to increase its focal length, resulting in a large illuminated field. For visual examination the blue glass filter is inserted in the sub-stage lamp, and for photographic work a ground glass is substituted.

The illumination of the sample is of utmost importance, not only in having an evenly illuminated field of sufficient intensity and of a constant value, but also the method of illuminating the sample is of great importance. As every method of illuminating a sand will show best, certain characteristics of a sand in the most pronounced manner, it is necessary to learn which method is most applicable for each examination. The different methods used to illuminate the samples may be divided into two main classes as: reflected oblique illumination from the top, and transmitted illumination from the bottom.

Reflected Oblique Illumination

The simplest one of these methods is the reflected oblique where the radiants are so arranged to project two beams of

light on the sand sample from two sides as shown in Fig. 2. The path of light rays may be traced from the radiant A through the two plano-convex lenses or condensers B and C. The diaphragm D is used to stop the colored light rays from entering the plano-convex lens G which projects a light beam on the sand sample on the slide. Some of the light rays are reflected into the objective lens O and their path may be traced in the diagram through the microscope. The combination of lenses at E is the eye-piece of the microscope.

When the sand sample is placed on a glass slide for reflected oblique illumination, a dark background will be seen or photographed. To see why this is true, trace the light rays in Fig. 3. Notice that rays 1, 3 and 4 impinge on sand grains and are reflected into the objective and they will produce the images of these grains. The rays 1 and 5 impinge on the glass slide and since the angle of reflection is equal to the angle of

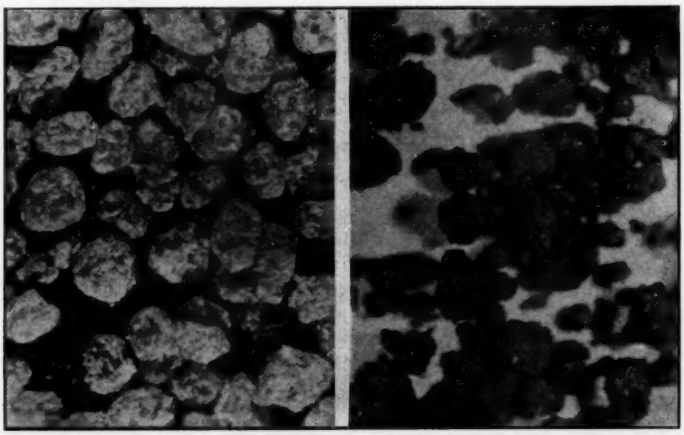

FIG. 4—REFLECTED OBLIQUE ILLUMINATION WITH DARK BACKGROUND FOR LIGHT COLORED SAND. SHOWING THE ROUGH CLAY COATING AND CLUSTERING OF SAND GRAINS. MAGNIFIED 18 DIAMETERS. NEW SYNTHETIC STEEL MOLDING SAND

FIG. 5—REFLECTED OBLIQUE ILLUMINATION WITH WHITE BACKGROUND FOR DARK COLORED SAND. SHOWING THE VERY ROUGH CLAY COATING AND CLUSTERING OF SMALL GRAINS TO THE SURFACES OF THE LARGER GRAINS. MAGNIFIED 18 DIAMETERS. SYNTHETIC STEEL SAND USED IN SEVERAL CASTS

incidence, these light rays never enter the objective, so the glass appears dark. A micrograph so taken is shown in Fig. 4. A dark background may also be secured by placing the sand on a black slide, or if more vertical lighting is used than shown in Fig. 2, a dark piece of cloth may be placed beneath the glass slide on which the sand sample lies. A dark background is particularly suited for sand that is light in color.

In order to show a dark-colored sand a white background is preferable. To secure the white background with the reflected oblique light place the sand sample on a white paper slide. The path of light rays will then be as shown in Fig. 6. In this case the rays 1 and 5 are not reflected at the same angle as they strike the paper, but at a much greater angle so that they enter the objective and the white paper will be seen as a white background. The advantage of this white background is very evident when the micrograph of Fig. 5 is viewed.

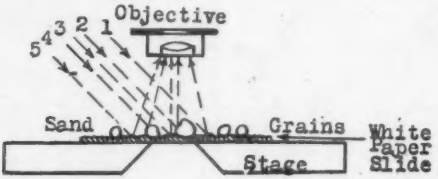

FIG. 6—DIAGRAM SHOWING THE PATH OF LIGHT RAYS WHEN USING PAPER SLIDE TO GIVE A WHITE BACKGROUND IN REFLECTED OBLIQUE ILLUMINATION

Sand grains that are dark in color and opaque are best shown using the reflected oblique light to give a white background.

Transmitted Illumination

When we illuminate the sand from the bottom, that is, from below the stage, we have transmitted illumination which proves a very satisfactory way to show the amount and the distribution of clay coating on the sand grains, and also to study the shape of sand grains themselves. To obtain a white background with this method of lighting Fig. 7 will be instructive. The light rays from the radiant fall upon the mirror of the microscope or camera stage and are reflected up through the

sub-stage condenser. The sub-stage condenser directs them on the object slide and light rays pass axially through the slide and object into the objective lens. This will make the glass slide and the sand grains that are transparent appear illuminated or white. Fig. 8 is a micrograph of a molding sand taken in this manner. Notice the white background and that shading of the sand grain is produced by the clay coating. Since clay substance is opaque, a heavy coating on a sand grain will appear dark.

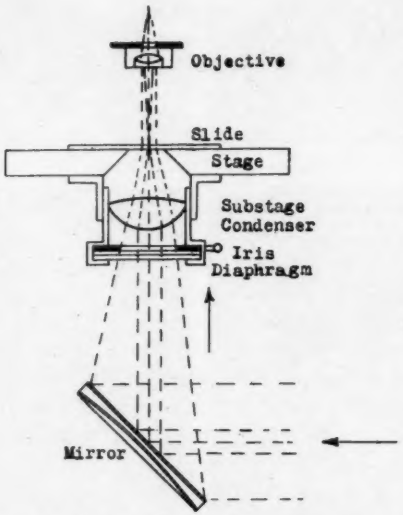

FIG. 7—DIAGRAM SHOWING THE PATH OF LIGHT RAYS FOR TRANSMITTED AXIAL ILLUMINATION

For producing a micrograph with a dark background with transmitted illumination, insert a center light stop in the lower part of the sub-stage condenser. The light rays can now only enter the sub-stage condenser in the form of a ring around the outside of the condenser lens. This causes a hollow conical light beam to pierce the sand grains. These very oblique light rays will only enter the objective lens if interrupted by an object like a sand grain. All of the other rays that pierce only the

glass slide, do not enter the objective lens so that the glass slide appears dark. Fig. 9 is an illustration of a micrograph for such a lighting effect. This dark background transmitted illumination is preferred to the white background, as it will enable one to interpret correctly the character of grain surface and to place the light transparent grains against a dark ground.

Reflected and Transmitted Oblique Illumination

A combination of the reflected and the transmitted oblique illumination will give a micrograph of Figs. 10 and 11, in which the uncovered sand grains appear white, and with good perspective also the nature of clay coating is shown more clearly than in any of the other methods. The intensity of both light sources must be varied for each particular sand to produce the best results.

Shape of Sand Grains

The shape of sand grains is divided into two classes, namely, those composed of angular and composed of rounded grains. With the aid of the microscope it is readily seen whether the grains are angular or round. A micrograph of graded Ottawa silica sand is shown in Fig. 12. Note how round these grains are and also that each indentation of the surface may be seen easily. Some grains are very smooth, while others have their surface indented and figured. A micrograph showing angular sand grains of a natural molding sand from which the clay has been removed is shown in Fig. 13. The surfaces and outline of the sand grains show irregularity with the exception of the three foreign rounded grains.

Fineness

To determine the relative fineness of a sand, the relative percentages of the various grain sizes are estimated. For example, note in Fig. 14 the micrograph of two sands. The sand shown in the lower portion of the illustration consists of very uniform grains and approximately 65 per cent of them would be retained on a No. 35 sieve. The sand in the upper portion is composed of grains of which approximately 10 per cent would remain on a No. 35 sieve, the majority being re-

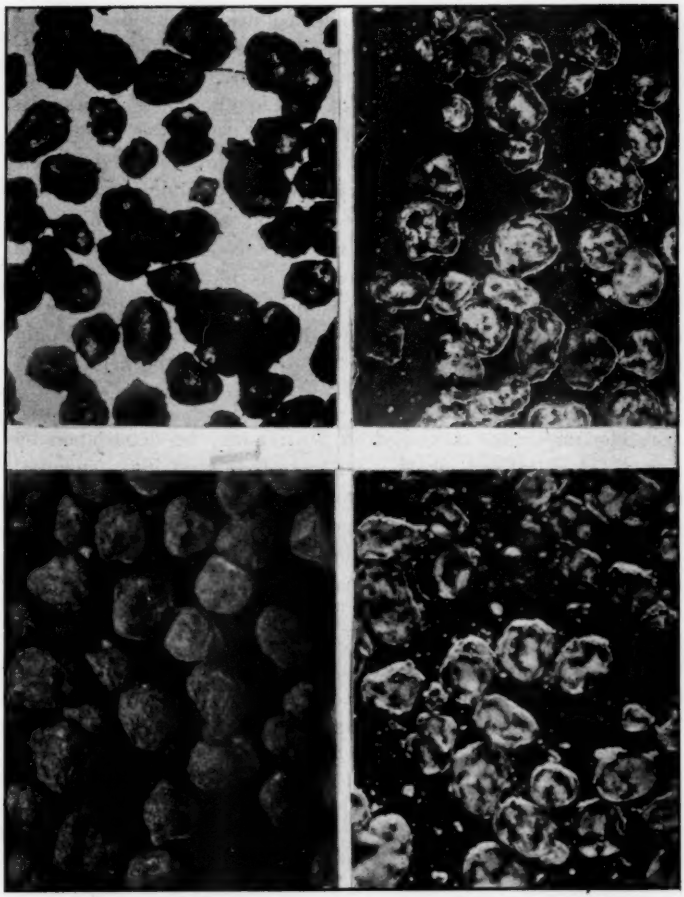

FIG. 8—TRANSMITTED AXIAL ILLUMINATION WITH WHITE BACKGROUND, SHOWING SHADING OF SAND GRAINS SURFACES BY OPAQUE CLAY COATING. 18 DIA. NEW STEEL SAND. FIG. 9—TRANSMITTED OBLIQUE ILLUMINATION WITH DARK BACKGROUND, WHITE PORTIONS BEING SILICA SAND GRAINS, DARK AREAS OPAQUE CLAY COATING. 18 DIA. NEW STEEL SAND. FIG. 10—COMBINATION REFLECTED AND TRANSMITTED ILLUMINATION, WITH INTENSITY OF REFLECTED ILLUMINATION GREATER, SHOWING COMPLETENESS AND SMOOTHNESS OF CLAY COATING. 18 DIA. NEW STEEL SAND. FIG. 11—COMBINATION REFLECTED AND TRANSMITTED ILLUMINATION WITH INTENSITY OF TRANSMITTED ILLUMINATION GREATER, SHOWING VARYING THICKNESS OF CLAY COATING. 18 DIA. NEW STEEL SAND.

tained on a No. 70 sieve. Possibly a quicker method would be to compare the unknown sand sample with a sample for which the fineness is known. The exact size of the grain particles may be determined by measuring with a micrometer eye-piece. Notice how the small grains in the sand shown in the upper portion of Fig. 14 seem to just fit and fill up the void spaces. This surely will result in a much lower permeability than when the grains are of uniform size. A micrograph which shows clearly how the proportion of the various grain sizes may be estimated by the aid of a microscope is indicated by Fig. 15. The sand shown in this figure is made from a blend of two sands, the resultant containing two definite grain sizes, large and small, the latter covering at last 90 per cent of the field.

Determination of Impurities

The impurities contained in a sand may be determined by a micro-chemical test which is no more than applying a chemical reagent to the sand sample by means of a small pipette. Each substance changes to a definite color when etched with a particular reagent. Some mineralogical substances may be seen without the chemical reagents, as can be seen by the two sands shown in Fig. 14. The lower is all silica and the upper contains some pure silica grains. Others are colored by a thin film of red iron oxide. Some yellow iron pyrite is also present. The coating on burnt sand grains may be determined by examining the grains of sand with a microscope. A micrograph of burnt sand is shown in Fig. 16. The following things may be noted; the white calcined clay coating on many of the grains, a few unaffected grains, several cracked sand grains, a large number of the sand grains coated with slag, and a large particle of slag high in iron content.

Clay Distribution

The uniform distribution of the clay throughout the sand mixture is a very great influencing factor in permeability, bond and nature of casting surface produced. A good distribution of clay of a dry mixture consisting of 9 per cent of clay and 91 per cent Ottawa sand is shown in Fig. 17. Notice how each sand grain is evenly coated with fine clay particles and

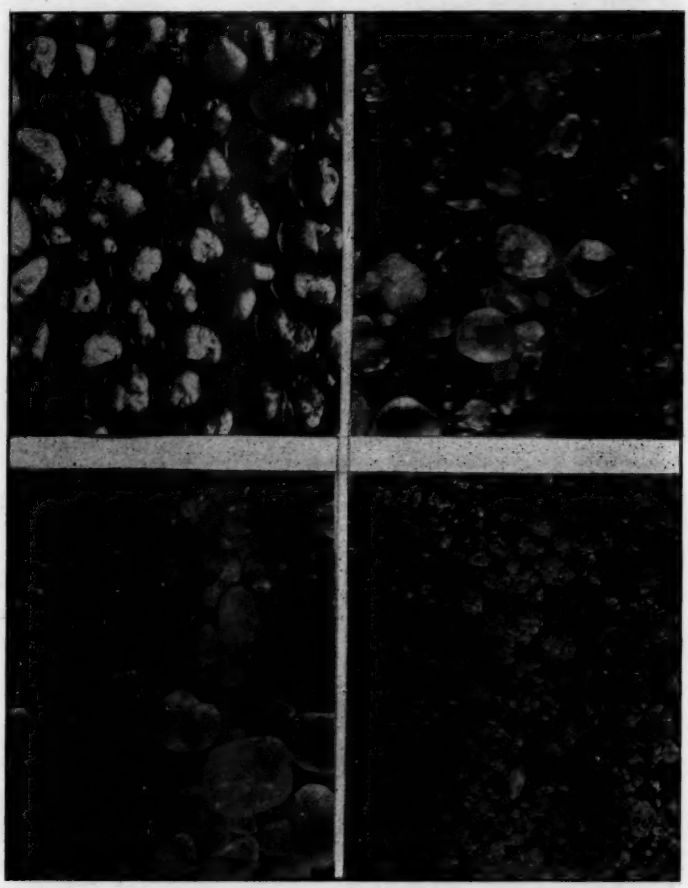

FIG. 12—GRADED OTTAWA SILICA SAND PHOTOGRAPHED WITH TRANSMITTED OBLIQUE ILLUMINATION TO SHOW THE CHARACTER OF THE GRAIN SURFACE. 18 DIA. FIG. 13—A NATURAL BONDED FLOOR MOLDING SAND WITH CLAY SUBSTANCE REMOVED, SHOWING THE ANGULAR SAND GRAINS. 18 DIA. REFLECTED OBLIQUE ILLUMINATION. FIG. 14—SAND GRAINS OF TWO MOLDING SANDS. THE RELATIVE FINENESS MAY BE DETERMINED BY COMPARISON. LOWER PORTION IS OTTAWA AND TOP PORTION IS A NATURAL HEAVY IRON MOLDING SAND WITH CLAY REMOVED. REFLECTED OBLIQUE ILLUMINATION. 18 DIA. FIG. 15—A NATURAL BONDED LIGHT BENCH MOLDING SAND CONSISTING OF TWO PRINCIPAL GRAIN SIZES. REFLECTED OBLIQUE ILLUMINATION. 18 DIA.

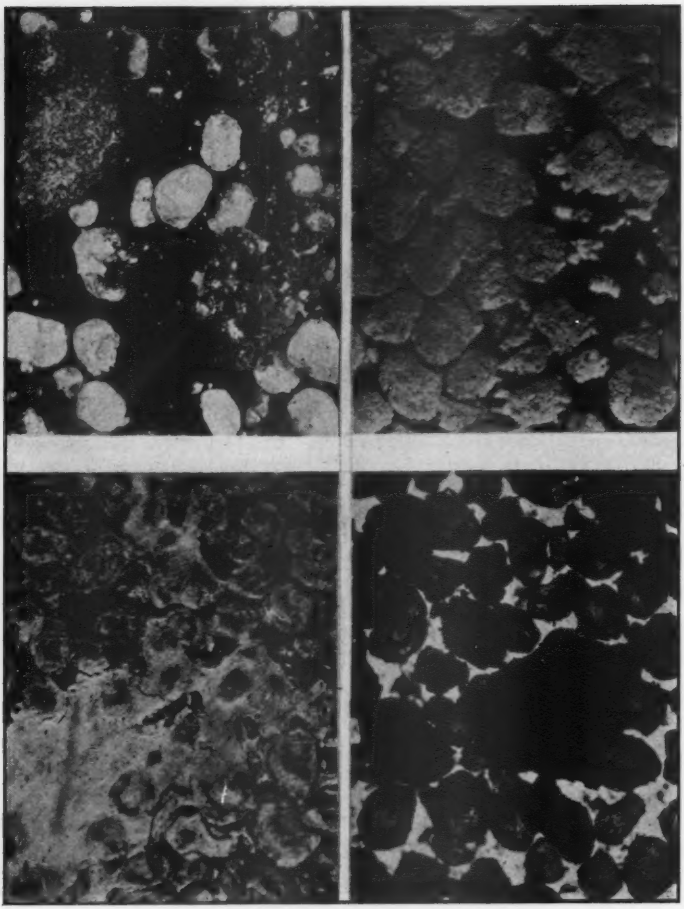

FIG. 16—BURNT SAND SHOWING THE CRACKING OF SAND GRAINS, CALCINATION OF CLAY COATING, AND THE COATING OF SOME OF THE SAND GRAINS WITH THE SLAG. REFLECTED OBLIQUE ILLUMINATION. 18 DIA. SYNTHETIC STEEL SAND.

FIG. 17—A DRY MIXTURE OF SAND AND 9 PER CENT CLAY, SHOWING A GOOD DISTRIBUTION AND COATING OF THE SAND GRAINS WITH GRANULAR CLAY PARTICLES. REFLECTED OBLIQUE ILLUMINATION. 18 DIA.

FIG. 18.—THE RESULT OF POORLY DISTRIBUTED CLAY IN THE MOLDING SAND WHEN THE FACE OF THE MOLD IS SLICKED. REFLECTED OBLIQUE ILLUMINATION. 18 DIA. SYNTHETIC STEEL SAND.

FIG. 19—TRANSMITTED AXIAL ILLUMINATION SHOWING CLAY AS DARK AREAS. THE CENTER LARGE DARK AREA IS A MASS OF POORLY DISTRIBUTED CLAY. 18. DIA. SYNTHETIC STEEL SAND.

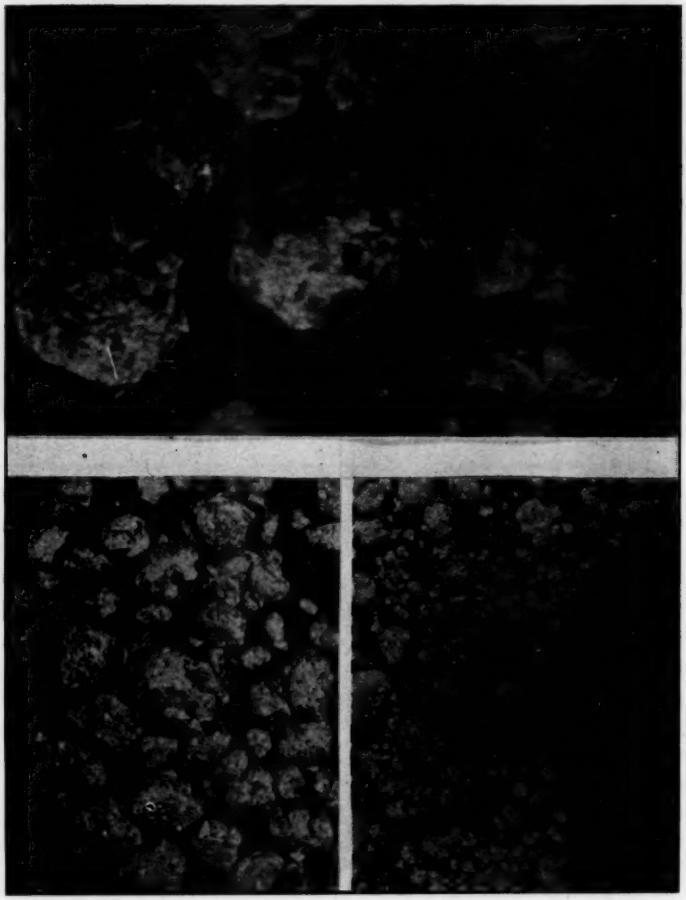

FIG. 20—HAND MIXED SYNTHETIC STEEL MOLDING SAND SHOWING THE INCOMPLETE CLAY COATING ON THE SAND GRAINS REFLECTED OBLIQUE ILLUMINATION. MAGNIFIED 50 DIAMETERS

FIG. 21—OLD SAND RECLAIMED BY ADDITION OF 2 PER CENT CLAY. SHOWING THE ROUGH CLAY COATING AND CLUSTERING OF SMALL GRAINS AROUND THE LARGE ONES. REFLECTED OBLIQUE ILLUMINATION. MAGNIFIED 18 DIAMETERS. SYNTHETIC STEEL SAND

FIG. 22—A NATURAL BONDED MOLDING SAND WITH A CLAY COATING OF CLAY GLOBULES. REFLECTED OBLIQUE ILLUMINATION. MAGNIFIED 18 DIAMETERS

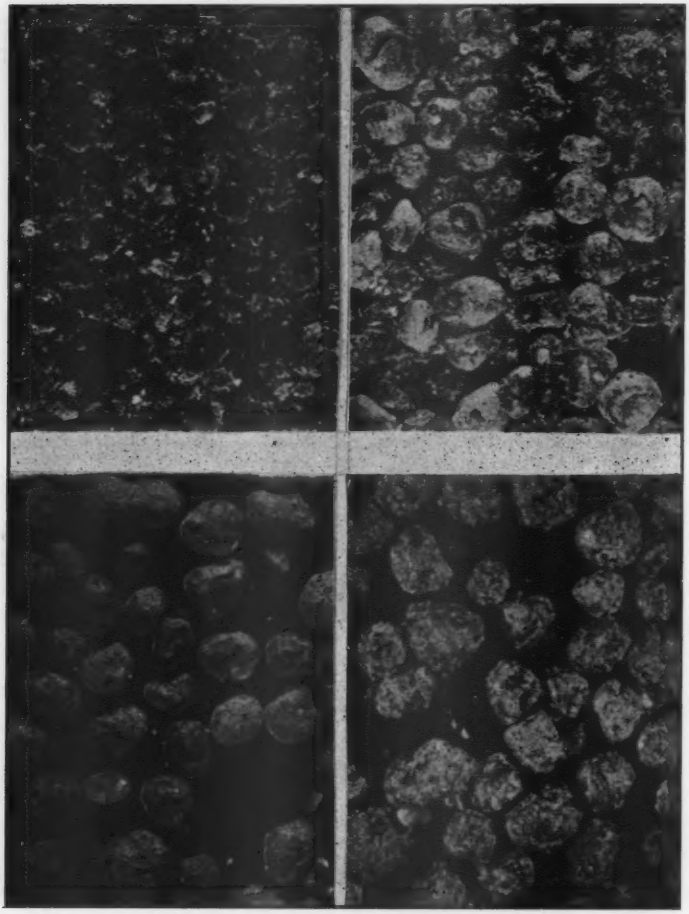

FIG. 23—JOLT RAMMED SAND MIXED WELL TO GIVE A GOOD CLAY COATING. A VERY SMOOTH SURFACE WITH NUMEROUS VOID SPACES IS THE RESULT. REFLECTED OBLIQUE ILLUMINATION. 18 DIA. FIG. 24—JOLT RAMMED SAND POORLY MIXED GIVING A POOR CLAY COATING, A VERY ROUGH SURFACE WITH LARGE IRREGULAR SPACED VOIDS. REFLECTED OBLIQUE ILLUMINATION. 18 DIA. FIG. 25—SAND TEMPERED WITH CORRECT AMOUNT OF MOISTURE TO GIVE BEST CLAY, HIGHEST BOND AND PERMEABILITY. COMBINATION REFLECTED AND TRANSMITTED OBLIQUE ILLUMINATION. 18 DIA. FIG. 26—SAND MIXED WITH EXCESS MOISTURE GIVING AN INCOMPLETE COATING RESULTING IN A LOW BOND AND PERMEABILITY. REFLECTED OBLIQUE ILLUMINATION. 18 DIA.

that there is really an excess of clay lying on the slide. When this is tempered, the excess clay will be picked up resulting in a good bond, permeability and a casting surface good for grain size proportioning. An example of what poor clay distribution will do is shown in Fig. 18. The large patch of clay will result in a poor permeability and a scab on the casting surface. The transmitted illumination is a very effective way to show the clay distribution in a sand. Fig. 8 and Fig. 9 are micrographs with this illumination, as is also Fig. 19. In this last mentioned micrograph a large patch of clay may be seen in the center of the figure, also one near the upper side. No foundryman would expect to get a good casting surface with patches of clay on the face of the mold. Poor clay distribution is caused by poor mixing it is true, but how many foundrymen know whether their mixing process is not classed under the poorer method? A microscope will quickly tell when good distribution is attained.

Completeness of Clay Coating

We can have good clay distribution and still not have a mixing process that will give a complete film of clay around the sand grain. For verification, study the enlarged micrograph in Fig. 20. The clay is correctly proportioned to each grain, but the coating is incomplete. For a more complete film of clay coating around each sand grain the micrograph of the same sand containing the same amount of clay, but mixed with a different process, is shown in Fig. 10. The clay coating of burnt sand rebonded with a two per cent clay is seen in Fig. 21. Notice how rough the sand grains become. As a rule if the sand is coated only in spots, the failure lies not in the amount of clay added, but is caused by the mixing process. A weak bond and low permeability is the result.

The clay coating of a natural bonded molding sand is shown in Fig. 22. It may be noticed that the clay coating does not consist of a film of clay, but of many globules of clay. That the nature of the casting surface is influenced by the clay coating on the sand grains is well illustrated by examining jolt rammed sand samples under the microscope. In Fig. 23

is shown a section of jolt rammed synthetic steel molding sand mixed by a good mixer so that the clay coating is good. The void spaces are very regular in size and one for each sand grain. The placing of the sand grains is such so that the surface of sand is very smooth which would give a good casting surface. Next examine the jolt rammed sand mixed by an inferior mixer as shown in Fig. 24, and note the irregularity of void spacing and also the irregularity of their sizes due to the nature of clay coating. The surface of the sand contains many large indentations due to the placing of the sand grains. This sand will give a rough casting surface as it does not form a good smooth retainer of molten metal.

Water Content

The exact per cent of moisture contained in a sand cannot be determined by a microscopic examination, but the point when the correct amount of water is added to give the best bond, and permeability can be determined. To illustrate this determination, first notice the micrograph of Fig. 25 and its smooth clay coating for it has been tempered correctly. Next examine the micrograph of Fig. 26 which shows the same sand with an excess amount of water added. Note how the clay coating around the sand grain is separated, caused by the clay losing its tenacity when too much water is added. If not enough water is added the clay coating will appear granular, and does not form a close film around the sand grain.

Conclusion

The microscope will give the best means of scientific inspection and the micrographic camera will serve as the best means of getting an indisputable record for present and future references. This equipment will not only help to choose mixing and reclaiming machinery, but will enable one to find the paying limit in many processes:

The Use of Chemical Reagents in Preparing and Rebonding Molding Sands

By H. W. Highriter, New Haven, Conn.

In the preparation and purification of clays for manufactured ware the ceramic industry has made valuable use of the fact that certain chemicals, principally alkalies, possess the property of deflocculating clays.

This deflocculation separates the small lumps of clay and minerals such as quartz, mica and feldspar, the clay becoming so finely divided that it forms a true colloidal suspensoid, or suspension in which the particles are so small that they do not settle, or settle only very slowly. The coarse impurities such as quartz and mica settle out and are removed, the pure clay remaining with the water from which it is removed by flocculation, a reversal of the above process using sulfuric acid, which causes the clay particles to unite, forming larger particles that settle more readily.

Besides aiding in the purification of clays, the correct addition of alkalies to the casting slip is essential in the casting of clay wares, where there is liable to be a serious loss because of insufficient strength of the clays in the dry state and while burning. Schurecht[1] found that the addition of alkalies to clay in the plastic state caused a surprising increase in the strength of the clays, in one instance this increase amounting to 400 per cent. Other properties that are influenced are: water of plasticity, drying shrinkage, fineness of grain, strength after firing and porosity.

Application to Reclamation of Molding Sands

A consideration of this principle of alkali addition suggests two possible applications to the preparation and reclamation of

[1]H. G. Schurecht, "The Use of Electrolytes in the Purification and Preparation of Clays": *Bureau of Mines Tech. Paper* 281, 1922, p. 6.

molding sand: first, that the bond of weak natural molding sands which would be satisfactory otherwise might be so increased by alkali addition as to render the sands suitable for use; and second, that in rebonding used molding sands by the addition of clays better results with less clay might be obtained through the deflocculation of the clay with alkali or other reagent. This latter would apply also to the production of synthetic molding sands from silica sand and clay.

A careful survey of the literature indicates that very little has been done along the above lines either in the foundry or the laboratory. There is no record of this practice having been followed in this country.

Green[2] describes the method used in German foundries for restoring the good qualities of molding sand. It consists in grinding aluminum sulfate or other compound of aluminum to a fine powder and mixing it with old sand, with the addition of a certain amount of water. Another and equally effective method is to mix aluminum sulfate and water in the proportion of one pound of the former to 12 pounds of the latter, stirring to a pasty mass and then mixing with the sand. One ton of sand requires 124 pounds of the pasty mixture. If the sand is to be used for cores instead of molds a slightly larger quantity of the mixture is added. The addition of amorphous silica, it is claimed, gives greater cohesion between the sand particles.

A United States patent (No. 1052514) has been granted to Poulson for treating foundry sand with aluminum sulfate and gelatinous silica or sodium silicate to render it cohesive. This appears to follow the German practice described by Green.

H. B. Hanley[3] has made considerable use of the principle of the deflocculation of clays in the rebonding of used molding sand at the foundry of the New London Ship & Engine Co. The clay was deflocculated to the maximum point with sodium hydroxide (caustic soda) or ammonium hydroxide, and this mixture was then added to the sand and mixed thoroughly in a muller type of machine. The total addition of the deflocculated clay took care of the necessary addition of bond and at the same

[2]Green, H. S., *Foundry Trade Journal*, v. 14, 1912, p. 292-293.
[3]Private communication to the author.

time tempered the sand. The work was carried out over a period of several years with good success.

The advantages of this process consist in the fact that deflocculation of the clay develops its maximum plasticity or strength of bond, permitting the use of a minimum amount of clay, and causes it to be so finely divided that the subsequent muller mixing produces a distribution of the clay more nearly approximating that of the ideal molding sand, wherein each grain of sand is evenly coated with a thin layer of bonding substance of high cohesiveness. The use of a minimum amount of clay is desirable not only from the standpoint of economy but also because successive additions of large amounts would make the sand too close. Clays for this purpose should be refractory, of high plasticity, and non-vitrifying.

Objection may be raised that sodium hydroxide is a flux, and repeated additions of it to the sand pile might result in such a concentration as would cause trouble from fluxing. Hanley does not indicate that there was difficulty from this source, probably due to the fact that the amount of sodium hydroxide added is relatively very small, probably not over a few tenths of one per cent of the weight of the clay, which is, in turn, a small percentage of the total amount of sand reclaimed. However, the use of ammonium hydroxide would eliminate this possible objection, for since it is a gas dissolved in water it would evaporate without leaving a solid residue.

The investigation which it is proposed to make covering this general subject could logically consist of a systematic study of the effects of the addition of various alkalies, acids and other reagents upon the properties, particularly bond, of a considerable number of molding sands selected so as to be representative of the main sources of supply, since sands having different bonding materials might react differently to chemical treatment. There would be included mixtures of sand, new and used, with clays. This work could be done in laboratories equipped either for ceramic research or the testing of molding sands, and the methods used would be those specified by the sub-committee on tests of the joint A. F. A. and National Research Council Committee on Molding Sand Investigation.

The results of the laboratory tests should be supplemented, in so far as the principal findings are concerned, with tests in the foundry to confirm the laboratory results and to determine such factors as the effect of the chemical treatment upon the life of the sand, casting surface, etc.

The researches made upon clays indicate that valuable results may be expected from such studies.

Reclamation of Core Sand

F. L. Wolf and A. A. Grubb, Mansfield, O.

The practicability of reclaiming the sand from defective and used cores depends in a large degree upon the kind of binder used in the original core sand mixture. For this reason it may be well to review briefly the various types of binders used in making cores.

Types of Binders

Core binders in general use may be classified into at least three groups according to the physical or chemical properties which give them their binding power. In the first group are the oxidizing oils such as linseed, soya bean, rape seed, corn oil, etc. They depend for their binding power upon the formation by oxidation of a tough solid which clings tenaciously to the sand grains. This reaction is not reversible, in other words, it is at present impossible by practical means to bring this tough mass, largely linoxyn, back to the oily state. In the second group are all water soluble binders such as dextrin, glutrin, molasses, flour, etc. They depend for their binding power upon the formation with water of a sticky material which forms a hard tenacious mass upon drying. Unless burned, this solid mass can be dissolved by water and restored to its original sticky condition. The third class consists of gums or resins which depend for their binding power upon the formation of a soft sticky mass when melted; upon cooling, the mass becomes hard and cements the sand grains together. The sticky condition of this binder can be restored by again heating above

the melting point. There are a number of binders marketed, which consist of mixtures of the different kinds mentioned above.

It is evident that water soluble and gum binders offer greatest possibilities in the way of reclamation. It may be possible to reclaim not only the sand but also that part of the binder which is not burned. On the other hand, the best we can hope for, in the case of oil-bound cores, is to reclaim the sand alone. Work done by H. M. Lane and other experiments by H. W. Gillett and E. L. Mack* have shown that when once oil-bound cores have been burned, as by contact with molten metal, the reclaimed sand requires more oil to produce a good core than does new sand. Our problem at the Ohio Brass Co. was somewhat different in that the material we hoped to reclaim had not been burned. About 75 per cent of the production of our core room consists of cores weighing about two and a half pounds each and having large prints which lay in the mold outside the castings and are not touched by molten metal. It was hoped that these prints, which are about 50 per cent of the weight of the cores, could be crushed and used again in our core sand mixtures. The experiments reported in this paper have had to do with the reclamation of such material which, in the first tests, had been bound with linseed oil and, in the latter tests, with dextrin.

Tests on Linseed Oil Bound Cores

A mixture consisting of 80 parts Michigan City sand, 15 parts sand blast dust, 5 parts powdered coal and 1.5 parts linseed oil was selected for trial, this being the mixture used for the insulator cap cores which provide the large prints referred to above. The prints were gathered from the molding floor and ground in a ball mill. They were then put through a No. 10 riddle. Ten parts of this recovered sand were substituted for 10 parts of Michigan City sand in the regular mixture and cores made and baked as usual. Little, if any, difference was noted. Twenty parts were then substituted and the cores appeared to be very good. After a few days' run, however, it was noted that the losses due to breakage were a little higher than usual so the oil content was raised to two parts. This remedied the trouble so we continued to use the mixture composed of 20 parts recovered sand, 60 parts Michi-

**Transactions of the American Institute of Metals,* Vol. XI-XII, 1917-18.

gan City sand, 15 parts sand blast dust, five parts coal and two parts oil.

Laboratory tests were then made in order to obtain more accurate data. The first tests were made to determine the effect of recovered sand on the strength, bond and permeability of cores. For this work, recovered sand from cores composed of 80 parts Michigan City, 20 parts sand blast dust and 2 parts oil, was used. Four batches containing different proportions of recovered sand but alike in other respects were made up simultaneously. The green bond was measured by making a core 1 x 1 x 12 inches in size and pushing it slowly over the edge of a glass plate, the average length of the broken sections being recorded. Test cores for permeability and strength measurements were then made and baked together on the same plate. Permeability was measured by drawing a standard volume of air through a core of standard size under standard conditions, the time required being reported in seconds. Strength was measured by breaking cores of standard shape in a Wadsworth core testing machine; the results were recorded in pounds per square inch. The cost of each batch of 100 quarts was then calculated based on prices current at that time: Michigan City, $3.05 per ton and linseed oil, $0.84 per gallon delivered. The sand blast dust was figured in at no cost while the recovered sand was taken at $1.25 per ton, this figure being determined by observations on a trial run and includes a reasonable allowance for overhead. Table 1 records the results of these tests.

Table 1

Mixtures	1	2	3	4
Recovered sand	0	30	40	50
Michigan City	80	50	40	30
Sand blast dust	20	20	20	20
Linseed Oil	2	2	2	2
Bond	1.28	1.26	1.30	1.24
Permeability	33	29	28	25
Strength	95	75	65	58
Cost per 100 qts	$0 816	.729	.697	.671

The results indicate that by replacing Michigan City with recovered core sand (from core prints) the green bond is not changed, the permeability value is lowered slightly, that is, the cores are made a little more open and the strength is greatly decreased. Mixtures Nos. 2 and 4 were next strengthened by the addition of linseed oil and the figures of table 2 were obtained.

Comparing these figures with those of mixture No. 1 it is seen that when using recovered core sand, the additional lin-

seed oil required offsets the saving in Michigan City sand and increases the cost some 10 or 15 cents per hundred quarts.

A test was next run on the regular cap core sand mixture mentioned above. Inasmuch as the recovered sand from these

Table 2

Mixtures	5	6	7	8	9	10
Recovered sand	30	30	30	50	50	50
Michigan city	50	50	50	30	30	30
Sand blast dust	20	20	20	20	20	20
Linseed oil	2.59	2.95	3.37	2.56	3.18	3.89
Strength	80	92	116	83	91	130
Cost per 100 qts.....	....$0.853	.929	1.016	.788	.918	1.067

cores contained both sand blast dust and powdered coal, proportionately less of these materials were added in the mixtures containing recovered sand. Forty parts recovered sand were substituted for 35 parts Michigan City, 3 parts sand blast dust and 2 parts powdered coal.

Twelve and 14 have less green bond and are slightly more open than 11; 12 is considerably weaker but when about 2.25 quarts of oil are used the strength equals that of 11. The cost, however, is about 5 cents higher.

The tests outlined above were made on sand recovered from prints gathered from the foundry floor. While the large part of these prints had not been burned, it was possible that that part nearest the casting had been subjected to rather high temperatures and was, therefore, having a deteriorating effect. It was thought that possibly more favorable results could be obtained by reclaiming sand from defective cores that had been thrown out before going to the molds, so tests similar to those described above were made on such material.

At the time these tests were made we were using 140-mesh silica flour instead of sand blast dust in some of the core sand mixtures so this test was made on a mixture composed of 80 parts Michigan City, 20 parts silica flour and 2 parts linseed oil. Such a mixture produced cores having a strength of 68 pounds per square inch; when 20 parts of recovered sand were substituted for an equal quantity of Michigan City, the strength was 44 pounds and when 60 parts recovered sand were used the strength was only 36 pounds. These latter mixtures required 3 and 3.8 quarts of oil respectively to bring them up to the strength of the original mixture and cost $1.15 and $1.12 per hundred quarts as compared with $1.00 when no recovered sand was used.

Similar tests were also made using that fraction of the recovered sand which passed through a 60-mesh screen. The weakening effect of recovered sand was even greater than when the whole sand was used. For this test we determined

Table 3

Mixtures	11	12	13	14	15	16
Recovered sand	0	40	40	40	40	40
Michigan City	80	45	45	45	45	45
Sand blast dust	15	12	12	12	12	12
Powdered coal	5	3	3	3	3	3
Linseed oil	1.5	1.5	1.76	2.04	2.33	2.64
Bond	1.33	1.19	.....	1.20	.....	.....
Permeability	33	30	.....	30	.....	.....
Strength	44	25	30	35	49	65
Cost	$0.736	.634	.689	.747	8.09	.874

the average fineness of each of the sands used and then calculated all the test mixtures to the same average fineness. The 60-mesh recovered sand had an average fineness of 94, Michigan City 56 and silica flour 172. The data and results of the tests are recorded in Table 4.

An error was made in calculating 20 so the fineness figure was lower than intended, as were also the bond and permeability.

The results of the above tests indicate that the dried oil binder which remains in the recovered sand not only has no further binding value but detracts from the binding power of further additions of oil. As mentioned in the early part of this paper, linseed oil, when once oxidized to linoxyn, cannot be brought back to the oily state. Further heating after it is once solid serves only to char and weaken it. When oil bound cores are crushed, this cement material is broken, part may be removed from the grains but practically all remains in the sand. When a new mixture is made up with such material and fresh oil is added, the oil forms a coat on the linoxyn. Baking hardens the fresh oil but chars and weakens the linoxyn so that newly formed cement cannot get a firm grip on the sand grains. Weak cores result.

Table 4

Mixtures	17	18	19	20
Recovered sand	0	15	30	40
Michigan City	80	70	60	60
Silica flour	20	15	10	0
Linseed oil	2	2	2	2
Average fineness	79.2	79.2	79.0	71.2
Bond	1.24	1.22	1.23	1.13
Permeability	29	29	28	26
Strength	67	45	30	19
Cost	$1.02	.952	.883	.812

It was thought that possibly the sand could be restored by burning off the linoxyn coat so a quantity of the 60-mesh material was placed in a heavy iron container and heated to 1700 degrees Fahr. for an hour with frequent stirring. Upon cooling the sand was examined under a low-power microscope; the grains appeared fairly clean and many of them showed a reddish tinge due probably to iron oxide. No other change in physical condition was noted. This sand was then used in mixture 19 and cores made up for test. Mixture 17 was repeated in order that cores from both mixtures could be baked together as a check. The following results were obtained:

Mixture No.	17	19
Bond	1.27	1.26
Strength	71	40

The heat treatment had evidently improved the sand but little, raising the strength from 30 to 40 pounds whereas the mixture containing no recovered sand tested about 70 pounds.

We are at a loss how to explain the fact that no greater improvement in the sand was obtained by heat treatment. We have made experiments on Michigan City sand heated to 1300 degrees Fahr. and obtain as strong cores as with sand dried at room temperature. We understand, however, that quartz undergoes certain transformations in physical condition at about 1070 degrees Fahr. and 1600 degrees Fahr. Evidently the first transformation does not affect its value for cores but possibly the second does. We are hoping to make tests burning off the linoxyn at temperatures under 1600 degrees Fahr. in the near future.

Tests on Dextrin Bound Cores

At the time these experiments were made we were using a mixture composed of 75 parts Michigan City, 20 parts silica flour, 5 parts sand blast dust and 2 parts dextrin. A quantity of core prints which had been knocked out of white iron castings was gathered from the foundry floor and ground in a ball mill. It was then put through a No. 10 riddle. Mixtures were made up and tested with the results shown in Table 5.

Table 5

Mixtures	21	22	23	24
Michigan City	75	70	65	65
Silica Flour	20	15	20	15
Sand blast dust	5	5	.....	.....
Recovered sand	.....	10	15	20
Dextrin	2	2	2	2
Bond	1.54	1.49	1.51	1.45
Permeability	35	33	36	33
Strength	31	39	44	47

The mixtures were made with view to obtaining the same bond and permeability. This was accomplished only approximately as the results show. There was, however, a marked increase in strength with increased proportions of recovered sand, indicating that there was some binding power in the recovered sand as was expected. To check these results a set of test cores was made from the recovered sand alone, and another set from sand recovered from defective dextrin bound cores which had not been in the molds, no new sand or binder being added in either case. Rather surprising results were obtained as shown in Table 6.

There was a marked increase in bond, possibly a small increase in permeability number and a marked increase in strength over the new sand. This increase in strength was unexpected so we repeated the experiment using 80 parts Michigan City, 20 parts silica flour and 2 parts dextrin. The green bond test was 1.25. Three plates of cores were made and baked as follows: No. 1 was merely dried out, No. 2 was baked to a slight brownish tinge while No. 3 was thoroughly baked to a definite brown color. Tests gave No. 1 a strength of 31 pounds, No. 2 a strength of 55 pounds and No. 3 a strength of 59 pounds.

Table 6

	New sand Mixture No. 21	Recovered sand core prints from foundry floor	Recovered sand, from defective cores
Bond	1.56	1.67	1.76
Permeability	37	40	42
Strength	34	44	55

Table 7

Plate No.	Bond inches	Strength pounds
1	1.28	82
2	1.30	89
3	1.42	26

A core from each plate was dropped in water and the rate at which they softened was observed. No. 1 went down first, while Nos. 2 and 3 stood up and even remained firm for several minutes indicating that thorough baking tends to make the binder the more resistive to water.

The cores from each of the above plates were next ground in a mortar, water was added and thoroughly mixed. No. 1 and No. 2 worked up very nicely but No. 3 was harsh to the touch and more or less lumpy. The green bond was measured and test cores for tensile strength were made up. Table

7 gives the results of this test. Evidently No. 3 had been overbaked for purposes of reclamation.

Table 8

Bake	Bond	Strength
First	1.54	36
Second	1.58	27
Third	1.61	41
Fourth	1.62	62

A foundry trial was next made using a mixture composed of 70 parts Michigan City, 15 parts silica flour, 15 parts molding sand and 2 parts dextrin. The green bond was measured, test cores for tensile strength were made and the rest of the sand was made into cap cores on a Demmler machine. After baking the cap cores were allowed to cool and were then ground up and mixed with water. Tests were repeated and cap cores again made. This process was repeated until the sand had been made into cores and baked four times. Extreme care was taken to see that the cores were baked only to a very slight brownish tinge and none were overbaked. The results are recorded in Table 8.

The cap cores produced, however, did not show this increase in strength. The first two bakes produced excellent strong cores but the third and fourth bakes were weaker. It is to be remembered that the test cores were rammed up by hand while the cap cores were blown on a Demmler machine. It is possible that this latter method of making the cores influenced the results.

Our next step was to put the process on a production basis. The ball mill was too slow so we tried crushing the cores in a Simpson muller type mixer, water being added with the cores. The process worked very well but we found it necessary to screen the sand through an electric riddle. No binder was added to the recovered sand and excellent cores were produced on the Demmler machine. After a few days, however, it was noted that some of the cores were a little weak, so one quart of dextrin was added to each 100-quart batch of recovered sand. The operators found that the sand stuck to the core boxes a little more than usual and did not work as smoothly but no serious trouble was experienced.

The process was continued as outlined above for three weeks. We then began using 50 parts of recovered sand and 50 parts of new sand in each batch, and added one and one-half parts of dextrin. This required more labor than when the recovered sand was used alone; the cores were crushed and

screened after regular working hours and the recovered sand was added to the mixtures made the following day. This sand worked better and produced excellent cores.

Considerable trouble was experienced with our small sand mixers when used for crushing cores. These machines which are of the muller type are very efficient as sand mixers but hardly heavy enough for constant use as crushers. A larger machine of this type would handle the work in excellent shape.

Costs

During the four weeks' practical test it was found that four men could crush and screen eight tons of recovered cores in about five hours. Allowing a reasonable figure for overhead, the recovered sand then costs about $1.25 per ton. New materials, exclusive of binder, for this sand costs $3.73 per ton delivered. At least one-half the dextrin binder is recovered so the value of this sand is about $4.00 per ton. The net saving then is about $2.75 per ton. We recovered about eight tons of cores per day so the saving amounted to about $22.00 a day.

Further Tests

About the time we were forced to discontinue our recovery process on account of wear and tear on the mixers, a new angle to our core sand problem developed. It became necessary to leave some of the dextrin-bound cores in the molds several hours and frequently over night. To guard against absorption of moisture it was therefore necessary to use oil with the dextrin or else turn entirely to a gum or oil binder. Tests are now under way to determine the binder best adapted to this job; meanwhile we are using half linseed oil and half dextrin by volume and are getting very good results. When the proper binder for this work has been adopted we expect to again take up the recovery problem. Tests will probably be run on cores bound with both oil and dextrin and also on cores bound with pitch or gum binders. We are also hoping to do some experimental work on the recovery of the burned sand from such cores as well as the unburned prints.

Conclusions

When the above tests were made we had no intention of reporting them to the American Foundrymen's association. They are, therefore, not as complete as they would have otherwise been. The results obtained, however, are negative as regards the recovery of sand from linseed oil-bound cores and more or less positive for dextrin-bound cores. Sand from linseed oil

cores, even those which have not been burned, is not as good for core sand mixtures as new sand. Not only is no binding value obtained from the oxidized oil, but a larger quantity of oil must be added than is required by new sand. The cost of this additional oil in the tests recorded above offsets the saving in cost of sand.

Cores bound with dextrin gave much better results. By crushing and screening we not only recovered the sand but also a large part of the binder. Cost figures taken on a practical trial indicate that such sand can usually be recovered at a fair profit, depending, of course, on the cost of the original raw materials.

Discussion—Reclamation of Core Sand

A. A. Grub.—This is merely a preliminary report of work being carried on and is in no sense complete. In doing this work we have had two aims in view. In the first place to try and reclaim some refuse sand we have on hand being daily produced in our foundry, and in the second place, to try to find local Ohio sands or combinations of these sands suitable for brass work instead of using high priced Albany sand. We are now making the tests. We are using a somewhat different sand from the standard tests because of the reason Mr. Wolf has already given, that the standard tests have not been adopted, so we had to use our own tests. Those are described in the first two pages of the report.

While this report is preliminary, the results thus far are certainly encouraging in that they show the possibility of a very cheap, very practical method of reclaiming refuse sand, that loose sand that is so far burnt out that we have had to discard it in the past in the brass foundry.

Chairman R. A. Bull.—Mr. Grubb, what method did you employ for ramming the cores?

A. A. Grubb.—We used a hand method, but made quite a number of them in order to rule out the errors that would be made by variations in that hand method.

Chairman R. A. Bull.—Do you feel that you did take care of that satisfactorily?

A. A. Grubb.—I feel that we did, inasmuch as by repeating the tests three times we got consistently the same results, and, by the way, the same man does these each day and has done it for the last three years, and the results of his tests are used as a guide in making our core sand mixtures, so we are forced to have a good deal of confidence in the results of these tests for that reason.

Chairman R. A. Bull.—Because you had that dependable individual?

A. A. Grubb.—It might well be mentioned that that is one point very strongly in favor of the standardization of these methods which the committee is undertaking to do; it will eliminate the possibility of just the kind of question that Chairman Bull has brought out.

Mr. Olson.—Under the head of costs, it says here that "allowing a reasonable figure for overhead, the recovered sand then costs about $1.25 per ton. New materials, exclusive of binder for this sand, cost $3.73 per ton delivered." I was wondering what sort of material is used that they are paying $3.33 a ton for.

F. L. Wolf.—It is Michigan City sand; the cost is mostly freight. It includes the binder and putting it up ready for use.

Mr. Olson.—Would it not be fairer to state the cost of sand exclusive of freight? because if you live near Michigan City, you pay only $1.20 a ton and are better off to use new sand, and the same in Chicago; we find it cheaper to use new sand.

Chairman R. A. Bull.—The application of that data of course has to be differently interpreted for each locality. It might be of some assistance to split the data to show the cost of freight and also to show the cost of preparation and the bulk cost or total cost of the binder addition.

Sand Conservation and Reclamation Tests Using The Doty Cohesiveness Testing Machine

By R. F. Harrington, W. L. MacComb, and M. A. Hosmer, Boston, Mass.

A general survey of the work performed in our laboratory in connection with the problem of sand conservation and reclamation, together with the application of the Doty cohesiveness testing machine*, discloses many interesting phases of the sand problem. At this time we do not feel that a sufficiently exhaustive study has been made of the various problems to arrive at any positive conclusions. We are confident, however, that the machine when rigidly standardized, so that the results obtained in various laboratories throughout the country may be properly compared, will be a vital factor in the solution of many of the problems encountered in the study of molding sand.

For the interest of the trade and with the desire to stimulate discussion and further investigation we are enumerating the inconsistencies which our investigation has indicated.

For the sake of clarity we have listed the tests in order, stating the object of the test, material used, method of procedure, data secured and results obtained. Results may be either in the nature of positive or negative deductions, or suggestions for further study and investigation.

Previous to tabulating the work done in our investigation, a few words in regard to the Doty cohesiveness testing machine, its applications and limitations, may be said.

We have applied it to the study of the various problems as follows:

First—To determine the effect of moisture on the cohesiveness of our new sand.

Second—To determine the difference, if any, between our new sand, which has been dried out and remoistened, and the same sand with original moisture content.

Third—Effect of ten minutes hand mulling on the cohesiveness of our new sand.

Fourth—Effect of grain size on the cohesiveness of sand; moisture, bond and other variables remaining constant.

Fifth—To determine the increase in cohesiveness of our bushing sand obtained by machine mulling.

Sixth—Extent to which machine mulling brings out the active bonding material as determined by the dye adsorption test.

We have found that when using sand of relatively small grain size, and properly mixed to insure uniform distribution of moisture, the results obtained are very satisfactory. Not only is the percentage of variation in the weights of different sections of the same bar consistently low, but the weights of the broken sections from different bars, made from the same sand, check very well. Results from tests made on our facing sand, enumerated in Table 1 will bear out the above statement.

Table I

Facing Sand Number	Bar Number	Weight of broken sections in grams				Average Weight in grams	Percent Maximum Deviation
		1	2	3	4		
1	1	191	198	193	191	193	3.6
1	2	193	196	193	189	193	3.7
2	1	190	196	191		192	3.2
2	2	195	197	192		195	2.8
3	1	178	174	179	172	176	4.1
3	2	172	167	179		173	7.2
4	1	212	222	207		213	7.2
4	2	210	217	210		212	3.4

However, when the test is applied to our gravel, due to its coarser grain size, poor distribution of moisture, and presence of pellets of clay, a greater percentage of variation in the weight of various sections of the same test bar is obtained, as might be expected. This is illustrated by Table 2.

Test No. 1

OBJECT—To determine the effect of moisture on the cohesiveness of our new sand.

Table II

Sample	Test Bar Number	Weight of broken sections in grams 1	2	3	4	Ave. Wgt Gr.	Percent Max. Deviation	Percent Moisture Content
Our Gravel	1	206	211	231	217	219	12.6	5.95
Our Gravel	2	226	232	213	202	218	14.9	5.70
Our Gravel	3	231	203	215	238	222	17.2	5.41
Our Gravel	4	186	187	206	221	200	18.8	4.80
Our Gravel	5	170	180	182	200	188	17.6	7.30

MATERIAL USED—New sand.

PROCEDURE—The sample for test was spread out on a concrete floor and the moisture allowed to dry out. Representative samples of this sand for determinations on moisture and cohesiveness were taken at regular intervals. In all, sixteen test bars were made and broken, results of which are tabulated below and a curve plotted as shown in Fig. 1, using the average cohesiveness as measured in weight of broken section in grams as ordinates and percent of moisture content as abscissi.

Table III

Sample	Bar Number	Weight of broken section in grams 1	2	3	4	5	6	Average Weight in grams	Percent Moisture
New Sand	1	158	156	176	166	166	161	164	7.96
New Sand	2	168	172	175	168	186		174	7.60
New Sand	3	165	177	192	183	179		179	7.32
New Sand	4	170	180	182	200			188	7.30
New Sand	5	178	178	211	185	202		191	6.69
New Sand	6	178	208	196	203	196		196	6.66
New Sand	7	215	220	212	242			222	6.25
New Sand	8	206	211	231	217			219	5.95
New Sand	9	190	205	229	267			223	5.90
New Sand	10	226	232	213	202			218	5.70
New Sand	11	231	203	215	238			222	5.41
New Sand	12	211	222	222				218	5.20
New Sand	13	211	217	231	236			223	5.12
New Sand	14	187	186	207	221			200	4.80
New Sand	14	192	176	186	182			184	4.62
New Sand	16	175	176	140	169	149		162	4.47

Study of Data of Test No. 1

A comparative study of the individual weights of broken sections from the same bar, and of similar bars, made up of the same sand, with small variations in moisture, will serve to show why we hesitate before arriving at any positive conclusion.

After calculating the averages for each test bar and plot-

ting these values against the moisture content as shown in Fig. 1, a study of the curve obtained brings out the following points:

1. Beginning at a maximum of 7.96 per cent moisture and decreasing same by evaporation, we get a corresponding and fairly uniform increase in the cohesiveness of the gravel, until the moisture content has decreased to approximately 6.25 per cent.

2. Varying the moisture content from approximately 6.25 per cent to 5.00 per cent has but little effect on the cohesiveness of the sand.

3. The cohesiveness decreases rapidly, however, as the moisture falls below 5.00 per cent.

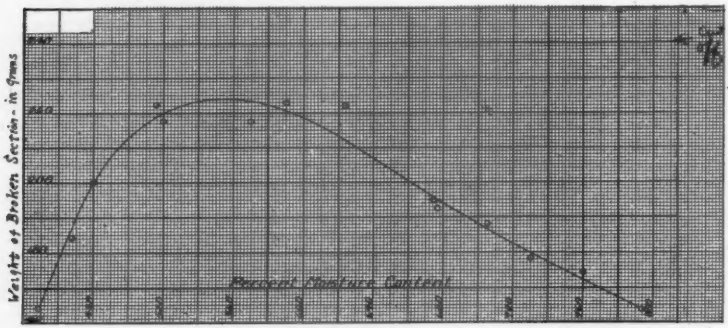

FIG. 1—CURVE SHOWING EFFECT OF MOISTURE ON THE BOND OF NEW SAND

4. The necessity of obtaining uniform distribution of moisture throughout the heaps before taking sample for Doty test is, therefore, imperative.

5. The importance of knowing the moisture content of sands when reporting cohesiveness values for means of comparison, cannot be made too emphatic.

6. That great care must be used in obtaining correct moisture in heaps.

Test No. 2

OBJECT—To determine to what extent, if any, the drying out of our new sand and remoistening of the same increases

its cohesiveness as compared with the same sand with original moisture content.

MATERIAL USED—New sand.

PROCEDURE—The sample selected for the test was divided into two portions.

Portion A—Contained the original moisture.

Portion B—Dried out and remoistened.

This test is a continuation of Test No. 1. Several bars from each portion with various percentages of moisture were made up and broken in the usual manner. The average value of the weights of broken sections from the individual bars were calculated and using the cohesiveness as measured in average weight in grams of broken sections as ordinates and percentage of moisture content as abscissi, curves were plotted similar to that of Test No. 1.

Table IV

Percent Moisture	Average weight of broken sections in grams	
	Sand dried out	Sand dried out and remoistened
8.02		
8.02		163
7.96	164	
7.74		174
7.60	174	
7.32	179	
6.94		192
6.92		194
6.69	191	
6.66	196	
6.37		197
6.25	222	
6.13		227
5.95	219	
5.92		236
5.90	223	
5.70	218	
5.41	222	
5.20	218	
5.12	223	
5.00		257
4.84		250
4.80	200	
4.72		254
4.67		220
4.62	187	
4.47	162	
4.30		212

Conclusions Drawn from Test No. 2

1. With a moisture content greater than 6 per cent, no appreciable increase in cohesiveness is obtained by drying out and remoistening the sand.

2. With moisture less than 6 per cent an appreciable increase in strength is noted in the sand which is dried out and remoistened. At 5 per cent moisture the increase amounts to 16 per cent.

3. Whereas we find that in the sand with original moisture content, when this moisture content varies between 5 and 6¼ per cent, there is little variation in breaking load, we note that in the sand which has been dried and remoistened, there is a progressive increase until a maximum of 5 4/10 per cent mois-

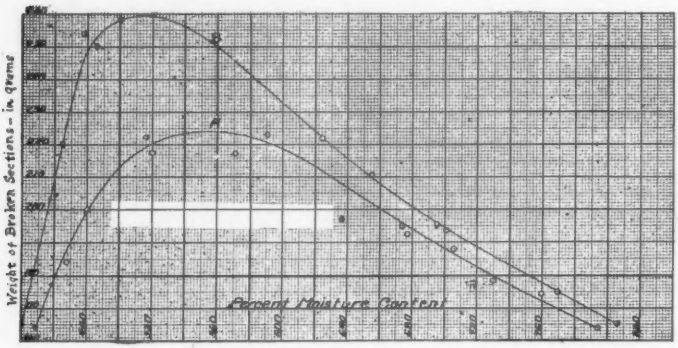

FIG. 2—CURVE SHOWING DIFFERENCE IN BONDING STRENGTH OF NEW SAND. CURVE A IS THE SAME AS IN FIG 1. CURVE B SHOWS THE INCREASE OF BOND STRENGTH WHEN THE SAND IS DRIED OUT AND THEN REMOISTENED TO ORIGINAL WATER CONTENT

ture is reached. Above this point a corresponding progressive decrease is noticed until a moisture of 4½ per cent is obtained. the strength of the latter at 4 7/10 per cent moisture compares favorably with that of the original sand at 5 1/10 per cent.

4. Does the increase in strength depend entirely upon the drying out effect or is it caused by the work expended upon it in the form of hand mulling, which is necessary to distribute the moisture uniformly throughout the sand.

Test No. 3

OBJECT—A study of the curves in Test No. 2 showing the difference in cohesiveness of the sand which has been dried out and remoistened as compared with the cohesiveness of the same sand, with original moisture content, clearly indicates that the sand which has been dried out and remoistened is appreciably stronger, when the moisture content is below 6 per cent. Are we justified in assuming that this increase in cohesiveness is attributed to the drying out of the sand, or are there other factors to be considered?

After the moisture was added to the air dried sand, work in the form of hand mulling was necessary to distribute the moisture throughout the sample. Since it is generally known that mulling increases the strength of molding sand, is it not possible that the increase in cohesiveness was due to the hand mulling which the sand received?

With the latter thought in mind work was undertaken to determine this fact.

MATERIAL USED—Millville gravel.

PROCEDURE—The sample for investigation was dried out and divided into three parts.

Part A—With original moisture content and was not worked. Four bars were made up and broken in the usual manner.

Part B—Similar to A except that the sand was worked by hand for a period of ten minutes, after which four test bars were broken.

Part C—Differed from B in that this sand was thoroughly dried out, remoistened to the same moisture as that of B, and worked by hand for 10 minutes. Test bars were then broken.

All results were tabulated and averages calculated and a comparative study made as shown in Table No. 5.

Results of Test No. 3 Analyzed

You will note that sand B with an average weight of broken

sections of 147.45 is 6 per cent stronger than sand A, which has an average weight of 139 grams. Also sand C with an average of 152 grams is 9 per cent stronger than sand A. Now knowing that hand mulling in Millville gravel containing 9 per cent moisture increases its cohesiveness 6 per cent and also that Millville gravel dried out and remoistened to 5 per cent has a cohesiveness of 16 per cent greater than the same gravel containing 5 per cent original moisture, we ask if this increase in strength can be credited to the mulling action which the sand receives when the moisture is worked into the sand?

Returning again to the curve in Test No. 2, and bearing in mind that only enough work in the form of hand mulling

Table V

Kind of Sand	Weight of broken section in grams	Average Weight in grams	General Average Weight in grams	Average Moisture Percent
A	130 131 128 147 149	137		
A	128 137 140 140	136	139	9
A	141 148 145 138 153	145		
A	133 137 141 143	139		
B	152 142 145 154 147	148		
B	144 148 153	148	147.5	9
B	136 156 142 157 143	147		
B	146 143 140 152 153	147		
C	155 150 152 154 157	153		
C	145 152 155 153	151	152	9
C	157 151 147 152	152		

has been done on the sand which is dried and remoistened, to mix the moisture uniformly throughout the sample, we find that with a moisture content greater than 6 per cent the curves nearly coincide.

With this data at hand and recognizing that the work done on the sand during the hand mixing does increase its cohesiveness when the moisture content is 9 per cent, we do not feel that this increase of 16 per cent in the dried out and remoistened sand, over the sand with the original moisture, can be attributed entirely to the mulling action. What factor then is responsible for this increase in cohesiveness?

A rational physical analysis of Millville gravel shows that it is composed of the following:

1. Silica grains of various sizes.

2. Coarse grains of feldspar.
3. Clay substance.
4. Transitional feldspar.
5. Black particles which are probably hornblende.

Close examination reveals the presence of numerous pellets of clay. If we believe that this increase in cohesiveness in the sand which has been dried out is due to the decomposition of the clay pellets and resulting better distribution of the clay particles around the silica and grains of feldspar, why is there not a corresponding increase when the moisture content is greater than 6 per cent?

To show why this is true, we offer the following explanation. It is quite apparent that the clay substance in sand takes up water thereby developing its plasticity with the addition of moisture, until this plasticity has reached a maximum. This maximum is attained at the same time that the clay substances ceases absorbing water, and until this point is reached, all the moisture then present in the sand is found in the clay substance.

This theory is substantiated by carefully examining a sample of sand containing a moisture of less than 6 per cent. The particles of silica and feldspar are found to be entirely free from moisture in this case, in spite of the fact that the sand appears fairly moist to the feel of the hand.

Now up to this point of 6 per cent moisture, the sand was dependent for its cohesiveness solely on clay substance which becomes stronger in plasticity simultaneously with increase in moisture absorbed. Beyond 6 per cent the excess water which will not be taken up by the clay substance, coats the grains of silica and feldspar and we now have not only plastic clay substance but in addition, water, to bind these grains of silica and feldspar together.

Since water is not as strong a binder as clay substance, the greater the percentage of the binder that is water, the less the cohesiveness of the sand. Consequently the excess moisture which therefore weakens the mixture, takes away from the sand that property of added cohesiveness obtained in sands of lower moisture content by mulling.

When the moisture in the original sand is allowed to evaporate, the loss of moisture takes place simultaneously from the clay, silica and feldspar grains, so that there is no time when the moisture present is contained by the clay particles alone.

To illustrate, let us take two sands of equal moisture content; sand A, which has been allowed to dry out from 9 per cent moisture, and sand B, which has been wet up from the dry state. Assuming this moisture content to be 5 per cent in both sands, according to our previous theory sand A would have part of its moisture present in the clay substance and part covering the grains of silica and feldspar. Sand B, on the other hand, would have the entire amount of its water in the clay substance. Now since the moisture content of the clay substance in sand B must, therefore, be more than that in sand A the latter must be the weaker sand which we have previously shown in Fig 2 would be the case.

Test No. 4

OBJECT—To determine the effect of grain size on the cohesiveness of sand. Moisture, bond and weight of sample taken were constant in each case.

MATERIAL USED—The test sand was made up of equal parts of the following:

A—1 part of fine beach sand
B—1 part of coarse beach sand.
C—1 part Wareham core sand.
D—1 part furnace bottom sand.

After a thorough mixing the above was dried out under the hot plate, screened and classified as follows:

Sand A—Portion which remained on the No. 6 screen. There was not enough of this sand to run a test.

Sand B—Portion which passed through No. 6 sieve and remained on No. 12. Not enough of this sample to make a test.

Sand C—Portion which was retained by the No. 20 sieve.

Sand D—Portion which remained on No. 40 sieve.

Sand E—Portion which remained on No. 70 sieve.
Sand F—All grains which passed through No. 70 sieve.

PROCEDURE—Test bars were made, keeping the amount of clay, water and sand constant. The mixtures were mulled by hand to insure uniform mixing of the sand, clay and water and the following bars made up and broken in the usual manner.

Table VI

Sample Number	Amount of Sand	Clay in Grams	C. C. Water	Average weight of broken section in grams
1	900 of C	350	70	222
2	900 of D	350	70	233
3	900 of E	350	70	255
4	900 of F	350	70	282

The individual results obtained are tabulated below and curve plotted with "breaking strength in grams" as ordinates and "grain size" as abscissi.

Table VII

Bar No.	Grade of Sand	Weight of broken section in grams			Average Weight
		Section 1	Section 2	Section 3	
1	C	222	222	221	222
2	D	231	235		234
3	E	251	258	255	255
4	F	282	282		282

Results of Test No. 4

The results clearly indicate that the effect of grain size in the cohesiveness of molding sands is a vital factor. At this writing we do not feel that a sufficient number of tests have been made in this problem to warrant the establishment of any rigid relationship between the grain size and the cohesiveness. However, we are confident that we have found a very valuable application for the Doty testing machine and hope that time may be available in the future to establish this relationship.

The fact that the test sand was made up of a mixture of four different kinds of sand is one very unfavorable feature of the test. The writer believes that better results or at least results of greater value would have been obtained if only one kind of sand had been selected for the original sample.

Test No. 5

OBJECT—To determine to what extent machine mulling increases the cohesiveness of our bushing sand as compared with the same sand mixed by hand.

To determine to what extent, if any, drying out, remoistening and machine mulling increases its strength.

MATERIAL USED—A mixture containing 32 parts of old bushing sand and 10 parts of new sand.

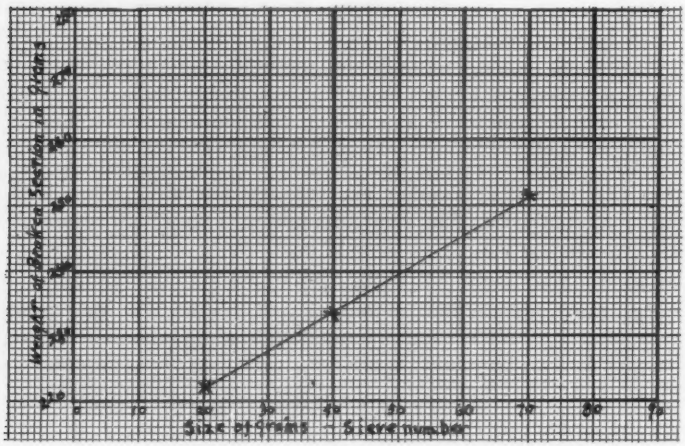

FIG. 3—CURVE SHOWING THE EFFECT OF GRAIN SIZE ON THE COHESIVENESS OF SAND

METHOD OF PROCEDURE—Sample was well mixed by hand and divided into three portions. From each, samples were taken for moisture and Doty test.

Portion A is hand mixed.
Portion B machine mulled for two minutes.
Portion C allowed to dry out in the open, remoistened and machine mulled for two minutes.

The results of Test No. 5 are shown in Table 8:

Studying the data of Table 8 we find that:

(A) The average moisture content of sand A is 8.14 per cent, whereas sand B, which is the same in all respects ex-

cepting that it has been mulled for two minutes, gives a moisture of 7.96 per cent, or a decrease of 0.18 per cent. Since

Table VIII

Kind of Sand	Weight of broken section in grams 1	2	3	4	5	6	Average Weight in grams	General Average in grams	Average Moisture Content Percent
A	90	111	102	101	104		102		
A	90	117	111	123	118		112	108	8.14
A	86	103	115	112	131	113	110		
B	135	146	141	147			142		
B	140	141	138	148	149		143	144	7.96
B	144	151	146	143	151		147		
B	140	146	140	151			144		
C	160	154	166	174			164		
C	163	166	162				164	162	7.62
C	156	160	155	151			156		
C	175	155	157				162		

A was hand mixed it was very difficult to secure a uniform distribution of the moisture, this fact is borne out by the results of the moisture determinations, the figures for which are given below:

Sample Number	Percentage Moisture	Average
1	7.59	....
2	8.00	8.14
3	8.82	....

(B) An increase of 36.7 per cent in cohesiveness of sand B over sand A.

(C) An increase of 48.6 per cent in cohesiveness of sand C over sand A.

Ignoring the fact that the moisture in sand C is less than in sand B, can we assume that by drying the sand and remoistening we increase its strength by an amount equal to the difference between 48.6 per cent and 36.7 per cent or 11.9 per cent. Let us return to the curve No. 2 in Test No. 3 showing the effect of moisture content on the strength of our new sand and assuming that the effects of moisture in both our new sand and bushing sand are comparable, we find that with our new sand, with a moisture content of 7.96 per cent we have a cohesiveness of 165 grams and with moisture of 7.2 per cent a cohesiveness of 185 grams; a difference of 7.96 less

7.12 or 0.84 per cent in moisture between sand B and sand C, gives an increase in cohesiveness of regular sand equal to 11.9 per cent; while the same decrease in moisture in our new sand produces a corresponding increase in strength of 12.1 per cent. Then the increase in strength of sand C over sand B is not due to the drying out effect but to the difference in moisture content.

Conclusions Drawn from Test No. 5

1. Two minutes of machine mulling increases the strength of our bushing sand by approximately 36 per cent.

2. With sand with nearly 8 per cent moisture no apparent increase in cohesiveness is obtained by drying out and remoistening.

3. An increase of cohesiveness in the same sand with the same mulling can be obtained by decreasing the moisture.

Test No. 6

OBJECT—To determine if by machine mulling our bushing sand we are able to increase the effectiveness of the clay substance present as measured by the dye adsorption test.

MATERIAL USED—Regular bushing sand containing 10 parts of our new sand and 32 parts of old bushing sand.

PROCEDURE—The above was mixed by hand and a portion (A) was taken for bond determination. A second portion (B) was machine mulled for two minutes and sample for bond determination.

Results of Test No. 6

Sample	Bond	Average Bond
Portion A	448	416
Portion A	384	...
Portion B	512	504
Portion B	496	...

We regret that time was not permitted for a more extensive investigation of this phenomenon. The little work done clearly indicates that machine mulling does increase the bonding strength of the clay substance present. In this test the increase amounted to 22 per cent.

Summary of Results of All Tests

As was stated in the introduction of this brief outline, we do not feel that a sufficiently exhaustive study of the various problems has been made at this writing to arrive at any positive conclusion, nevertheless, a careful examination of the foregoing seems to bring out certain relations which may or may not hold true at all times, but which are, nevertheless, of interest, and may serve to stimulate further study in this direction.

The salient points, therefore, are enumerated in the following general summary:

1. The Doty method of cohesiveness testing when properly standardized is an excellent method of comparative work.
2. Moisture plays a vital part in comparing the strength of sand, and never should be omitted when reporting comparative tests by the Doty machine.
3. With a moisture content of less than 6 per cent, an appreciable difference in the strength of two sands is noticed when one is dried out and remoistened to the original percentage, while the other retains its original moisture.
4. Drying out and remoistening increases the cohesiveness of sand when the moisture content is below 6 per cent, but above 6 per cent moisture, its added strength is offset more or less by the weakness of excess moisture present.
5. All other factors being constant, the cohesiveness of molding sand varies as the grain size.
6. Machine mulling brings out to a more or less extent the active bonding material as determined by the dye adsorption test.

With the above thought left in the mind of the reader, it is hoped that this brief resume of work thus far accomplished may contribute something in thought, or actual information of value to the extensive work now being carried on by the American Foundrymen's Association committee on molding sands, and to such foundries as are engaged in similar work; and that it will point out to others the vital importance of the great problem of the foundry today—that of sand conservation and reclamation.

Discussion—Sand Conservation and Reclamation Using the Doty Testing Machine

Dr. H. Ries.—Now as to this difference in strength between the sand which contains the original bank moisture and the sand to which the moisture has been added, I have a suggestion to make. In the paper by Mr. Highriter he has called attention to chemical reagents as affecting the bonding strength of sands. Now we know of course that tap water is not of the same composition in all localities, it may vary in its composition; this is a mere suggestion, but I am wondering what effect the difference in the composition between different tap waters might have on the strength of the sand. That is a point I should like to see tried out. I presume most of us who made these bonding tests have been using tap water and not distilled water.

Mr. M. A. Hosmer.—We used tap water in these tests.

Dr. H. Ries.—I notice your highest strength for Millville gravel is 257 grams.

On some of the Millville gravel, I have run, I have obtained a figure as high as 298; that represented the average of several bar tests.

Chairman R. A. Bull.—Therefore the water question.

John Petty.—I would like to offer a suggestion. I understand this Millville gravel was received in the original state and tested with the original moisture content, I understand that you have two kinds of moisture, free moisture and combined moisture; in drying this material out, you get rid of both free and combined moisture; in re-wetting this sand, you do not get the combined moisture, but you get the free moisture; in other words, your sand, to a certain extent, is dehydrated; consequently while you may re-wet the sand, you only get the free moisture content but do not get the combined moisture, so

there is a variation between the one and the other so far as moisture goes.

I think it is almost impossible to get your combined moisture back in the same condition as it was in the natural sand.

R. J. Doty.—I think the answer to that question remains in the temperature at which the sand was dried out. If it was dried out at a specific temperature, 100 degrees Cent., the combined moisture is not attacked, hydrated water is not driven off at that temperature; the only water that is driven off at that temperature is the free water, and that can be replaced.

Chairman R. A. Bull.—At what temperature did you try it?

R. F. Harrington.—At room temperature, so that only the free water content would be driven off. I think Mr. Doty's point is exceedingly well taken.

Chairman Bull.—What length of time you did allow moisture to remain before testing?

R. F. Harrington.—Practically immediately, in 10 or 15 minutes.

L. H. Cole.—If you had added moisture to a top dried clay, would you get better plasticity after a certain length of time?

R. F. Harrington.—I believe it does; I believe that is the answer to some of these problems of storing; I believe the sand to which the moisture was added, if 3 or 4 hours or 24 hours had been allowed to elapse, I believe that the strength of that sand would have been further increased, but even without that added possibility, we obtained a marked difference between the remoistened sand and moist sand.

Chairman R. A. Bull.—It was with the conviction that that point Mr. Cole has made is true that the subcommittee stipulated a particular time to rest the sand before testing.

Dr. H. Ries.—I am glad that point was brought out about the necessity of letting the sand stand after the water has been mixed with it, because it does make a greater difference in the results. If you do not let it stand to temper it and the moisture permeates it thoroughly and evenly through the mass, it makes a great difference in the results.

N. T. Booth.—My question is a little bit outside of the line of the paper, but the question is in connection with moisture and applies to the green sand steel casting man. I would like to know what has been done in determining the correct percentage of moisture in heap sand and how they arrive at it.

R. J. Doty.—I cannot answer that question as to whether 6 per cent is the right amount of moisture or not. Something over two years ago, we attempted to determine what is the right amount of moisture. There were a lot of physical problems entering into that; the nature of the work, the size and amount of metal, etc., and I do not know of any way by which we can say that a certain percentage is the right amount of moisture for a mold. What we are doing is to keep an accurate record taken at various times during the day of the moisture in our heap sand and our facing sand. Those records are plotted. We have those moisture contents with other data plotted for a period of more than two years, and we begin to believe that now we are narrowing that question down to rather close limits so that we can say, in our own particular case, that a moisture of about so and so is correct. We use less than six per cent in our particular case.

A Physical Test for Foundry Sand

By Eugene W. Smith, Chicago

It has become an almost universal practice among foundrymen when their losses become excessive, to gather together, around the scrap pile, everyone who might be interested, and *sometimes those who have no interest,* and hold what might be called post-mortems, over the losses which were caused two or three days and sometimes a week before.

There is a mysterious something about these inquests which seems to create a desire in each of the "Jury" to advance a theory as to the cause of the entire loss, regardless of its fitness to the individual items, without offering any preventative measures. This results generally in someone's being reprimanded, who, if the truth were known, was in no way responsible for the loss.

These gatherings around the scrap pile seldom result in anything satisfying to the one most interested, the man who pays the bills and receives scrap in return.

Arguments occuring at such a time create little frictions which tend to disrupt the general organization, and result in no adequate return. By the time matters have quieted down, the order has been completed and the pattern returned to the vault or customer without anything being done. When the pattern is brought back for a future order these incidents are usually forgotten and the same errors occur again, calling for another post-mortem. It seems to the writer like trying to keep up with the times by reading last week's newspapers. Would it not be wiser to arrange an ante-mortem procedure and anticipate the losses by "Consultations" before, not after?

Some Essentials Which Should be Considered

Three things are essential to effect a cure; good equipment, good metal, good sand.

The two former are easily acquired, but who can answer "What is good sand?" Chemistry will answer as far

as the various elements are concerned and some physical tests have been devised to compute the strength of sands. The foundryman, however, has depended almost entirely on the old "squeeze and feel" method to test his sand in use and to select his new sand.

If for but one day all of the foundry loss in this country could be placed in one pile, how large would it be and what would it mean in cash value? If only a small percentage of this loss could be saved by sand control, what would it mean to the foundryman in capital invested? It is safe to assume that 50 per cent of all casting losses can be traced, directly or indirectly to some controlling condition of the sand in molds or cores.

Selection of Sand

Numerous things serve to create these conditions; First, the selection of sand which is properly suited to the class of castings to be made. In making this selection the following molding and casting requirements must be considered; (1) the finish of the casting can be determined by the grain size; (2) the wearing qualities or life of the sand can be determined by the conditions to which the sand may be subjected; (3) the temperatures; (4) the weight of metal in the castings to be produced, and (5) the class of metal to be used; monel, steel, malleable iron, ferro-steel, cast iron, brass, aluminum and other nonferrous metals.

For the higher temperatures, sands which have high heat-resisting qualities must be selected. This may be determined by considering the class of rock from which it may have come. A sand which has its origin in slate or lime-stone should not be expected to resist heat as well as that which comes from silica or volcanic rock.

In order to ram the molds properly and still have the sand open enough to allow the gases to escape, the permeability of the sand to gases must necessarily be considered. If this is not done the closeness of the sand may result in losses due to its resistance to the gases formed by the metal.

Another very important item is the cost of transporta-

tion. Many foundrymen purchase their sand by its reputation, paying high freight rates, when by proper methods of selection, a suitable sand for their particular need might be found almost at their door. Again some foundrymen select a sand on account of its cheapness and make up for it later by paying for further post-mortems.

In some foundries reclamation of sand may be considered to advantage, where the heavier grades of sand are used and the core-sand used is mainly from the gang-way, as is the practice in plants making heavy castings.

But, in most instances, it appears to the writer a folly to try and reclaim sand which has deteriorated by the addition of large quantities of fine core-sand and which has passed through the tumbling mills or rattlers and been filled with the finer particles of iron. It does not seem practical to spend more money for labor to reclaim it than would purchase an equal amount of new molding sand. It would be far better to practice conservation and stop the prevalent waste of new sand and its abuse by improper foundry methods.

There is no other material purchased for foundry use which is so little cared for as molding sand. In many instances perfectly good molding sands are destroyed by storing them in the open and subjecting them to all sorts of weather conditions.

Many foundries leave the distribution of new sand to the laborer and to the whim of the molders. This is a most prolific source of waste. The money involved does not appear to affect those who should have the greatest interest. If it were only the loss of sand, it would not be so serious, but the resultant loss of castings from improper distribution is enormous.

Aside from the finish of the casting, the permeability of the sand and its heat resisting qualities, there is one more requirement for a good molding sand, which is probably the most important factor, that is the bond or clay content.

Nature by constantly disintegrating the rock and depositing it in the lower levels, grinds and prepares a cement-like substance which by its cohesiveness, ties each grain of sand to its neighbor without filling the interstices between the grains.

When this bond is dried by pouring metal into a mold, it releases the grains, permitting the removal of the castings, after which, by the addition of moisture and tempering, the cohesiveness of the sand is restored.

As there is a limit to the strength of this bond and as it is weakened by the excessive use of sea-coal, or core-sand from the castings, it cannot reasonably be expected to do double duty. Thus it becomes necessary to renew this bond occasionally by adding new sand. If too much is added, and the bond becomes excessive, it adheres to the castings and is carried away causing waste of new sand and increasing the cost of cleaning.

Although water is necessary to the retempering of the sand, it is an error to assume that adding water is adding bond. Just sufficient water should be added to the sand to restore it to its proper molding conditions or temper. Excess water usually results in such losses as blow holes, cold shuts and slaggy casting, caused by boiling metal.

The full benefit of this bond can only be had by thorough mixing. Many excellent devices have been provided for this purpose, but there is a great difference between them, some riddling or sieving the sand and others pressing or rolling it. By the former method, after riddling the sand or cutting it over, sufficient time is required to temper it before using. By the rolling or pressing methods, the sand is usually well enough tempered for immediate use.

The difference in the color of the sands, yellow or red, created by silicates of alumina, or silicates of iron, do not appear to have any particular bearing on their usefulness for molding purposes. Equally as good sand for all classes of castings may be had from either.

In all of the foregoing remarks, we have purposely avoided as far as possible any reference to the chemical,

mineralogical, or geological characteristics of the sand and have tried to present facts to you from the viewpoint of a molder, and have also tried to show the necessity of some method, which would serve as a common means of communication and study, to assist us in determining:

The relation of our losses to sand conditions.
How to avoid these losses.
How to select sand suitable to the class of product desired.
The proper amount of bond needed to produce good castings in our widely varying class or grades.
How to anticipate our loss by reducing the source.
How to determine wearing qualities.
How to stop waste.
How to provide the desired finish.
How to conserve new sand.
How to provide permeability.
How to maintain uniform conditions from day to day.
How to stop abuse of sand.

The vibratory test method is offered to you for this purpose, and I feel confident that when its purpose becomes fully understood, it will be found a valuable assistant, if properly applied.

The foundryman will find it a help in avoiding loss. The sand producer will find it a help in providing the foundrymen what they need. The student will find that it opens up a new and valuable field of study.

The vibratory method of testing sand, the details of which are given further on in this paper indicate what the writer has been doing in a practical way to aid in controlling his sand mixtures, although it does not necessarily represent the latest technical information on the subject.

I feel that I have only scratched the surface in studying sand under the vibratory method and have no doubt but further study will give much interesting and valuable information.

I wish to state here that in forming the collection of sands, which are shown at this convention, I have been greatly assisted by the sand producers in all parts of the country, and all whom I have met have expressed one desire, and that is to provide the foundryman with what he wants, and as he wants it.

Speaking of the collection, close study of it, while here, will prove profitable as well as educational.

It would be impossible to include a list of the many sand deposits in this country in this paper.

It is noticeable, however, that Eastern sands average much lower in bond than the Western or Southern sands although this must not be considered as an advantage to either. Thus the Eastern sands permit much heavier pressure and ramming, but weaken much faster and require greater renewal than the others. There is no good reason why strong bond sands cannot be found in the East, just as more open sands may be found in the West and South. There has never been any way of determining the bond required for blending purposes.

The method of testing sands described below has been successfully used by the writer in controlling the quality of the sands in daily use at the plant with which he is connected and also for studying new sands with a view of determining their fitness for use in this plant.

Method of Making Vibratory Test

Use a 10 or 12 ounce clear glass bottle, 1¾ inch in diameter, 6 or 8 inches high. The same as in common use for oil samples.

Rub the sand lightly to remove the lumps. Fill the bottle one quarter full of the material to be tested.

Fill the balance with clear cold water and shake thoroughly.

Stand the bottle on any foundry vibrator plate, hold down firmly and vibrate until the heavy grains are all down. Then allow it to stand until the water becomes clear. The bond and silica will be found divided by a distinct line.

Provide a small rule, the inches divided in tenths.

When the solution is fully settled measure the total, then measure the bond, or upper part, following by the silica at the bottom.

Divide each by the first figure. The result will be the percentage of either.

The presence of "yellow" will indicate alumina oxide and "red" the iron oxides. Sometimes both are distinctly shown in the sample but in most cases their presence is only shown by the varying shades.

The fineness may be easily determined by general observation.

What the Method Provides

This method provides the foundryman, the management and the purchasing agent, the producer, salesmen and students with a means of separating by the vibratory method the sand and determining the approximate proportion of finely divided material, most of which is undoubtedly silica, and the ferric and alumina oxides by the color; also a visible test of the fineness of the sand sufficiently accurate to determine the class of work for which it is best suited. Its simplicity insures its value as a substitute for the old squeeze and feel method of selecting foundry sands.

A suitable rack, in a light place, holding six bottles one for each day in the week, samples taken each afternoon, thoroughly vibrated, settling at night, measured and marked with small oval labels, each morning, show the figures of bond and silica. These figures governing a "curve" record which is shown in combination with the daily losses —will enable the foundryman to maintain a uniform condition of his sand.

Close observation of the curves will provide many surprises. For instance, if these was a sudden increase in the bond curve, without any known change in the amount of new sand used, it might indicate that fewer molds had been made or a number of men were off. If there was less sand in circulation and the same new sand added, the bond would be stronger.

This shown immediately in the curve warns the foundrymen of the necessity of cutting out the bond and thus saving loss.

Without such a test the foundryman would have no warning until the loss showed up a day or two later.

In presenting this method for the consideration of the foundrymen, there is one thought I wish to convey, and that is, that despite many surprises during my close study of it I am satisfied that it is reliable. By its use, with proper application and with close study of your sand conditions, I feel confident that you will avoid many of the post-mortems mentioned at the beginning of this paper.

It has occurred to the writer that as there are so many sands in the collection which show three and four divisions, and such wide variations in color and fineness, that there is a wide range for study on the part of the student.

And, as it is very noticeable that wherever both alumina and iron are present, in three divisions, the alumina is *always* shown with the finer and the *iron* with the heavier grains, the alumina always *above* and the iron *below*.

In each of the foregoing there is an opportunity to ask "why?"

Many questions may also be asked regarding the "silt" or the very finest divisions of the silica, and its effect upon castings produced, and there are many other characteristics which the foundryman has not the time or opportunity to study.

Discussion—A Physical Test for Foundry Sand

Mr. Parrish.—I think Mr. Smith's talk is very commendable and worthy of a great deal of consideration. We have been following Mr. Smith's practice in Elgin and it has produced good results. I think he has set the keynote when he says that each individual foundryman must study his own conditions.

Dr. Richard Moldenke.—I believe that Chairman Bull is right in saying that Mr. Smith's presentation of what he has worked out has caused practical foundrymen to go a little further into their sand question, and in doing so they have improved their sand. I have attended all the sand research committee meetings and I was surprised and pleased to see how every one of the committee felt delighted that Mr. Smith has done this practical work. We also know, however, in the East particularly, where we have different sands, that there is just a chance of running off on this, that where the sands are nice and strong, it doesn't matter so long as you get the castings, whether they are 10 times as strong, but when it comes to the point where, due to the lack of a bond in the sand, your cope drops, we have to go a little further.

A. E. Hageboeck.—I speak as the president of the Tri-City Foundrymen's association. At our January meeting we had Mr. Smith with us in Davenport, Rock Island and Moline. At the March meeting we had a little time on our hands and we had some discussion on sands and Mr. Smith's method and tried to find out what the foundrymen have done during the two months' period. I understand now that quite a few of our members are using Mr. Smith's method, and I just heard a gentleman say that he had reduced his loss 3 per cent. I want to say that Mr. Smith's method is helping the foundrymen and giving them, as he said, a yardstick and, therefore, I think

we should all thank him and agree that he is giving us something that we can use in our everyday practice in the foundry, and that the small foundry can use. The more elaborate tests are fine and are all right for the larger plants, but where the smaller plants cannot employ those tests, certainly Mr. Smith's test has a very distinct value.

J. Ploehn.—I am connected with a foundry that made a saving of about 3 per cent since January in this way. We are running a continuous factory; the sand is used over several times a day, how many I do not know, but sometimes we float along and get along fine, and then we bump into trouble. The first thing the foreman did, he put some coarse sand in—we have two kinds of sand, coarse and fine—he did not know which kind to put in, but since we have put in this test, the foreman takes a test every day and as soon as his bond gets a little too much he puts in a little of the open sand, not just sand, but open sand, and when it gets a little too open and the bond gets less, he puts in the fine sand and our losses since January have cut down 3 per cent; not all at once, but gradually, which is quite a saving, and our sand today is in fine shape and I just want to leave that as a measure of what this will do from a practical standpoint. These scientific tests are fine for blending or for geological surveys and for our information later on, because our sands will be getting scarcer, our requirements will be getting closer, but if you once find the sand, by this method you can get the same thing day by day and every hour of the day, if you want to, especially in a foundry that is running continuously like Mr. Smith's and our own.

Mr. Van Brau.—It seems to me that the benefit to be derived is in giving the foundry foreman a very simple test where he is able to maintain that bond uniformly. The nature of the bond, the fineness test and all that, has been determined before we purchase by our own laboratory, but we cannot run to the laboratory and ask them when to put in a little new sand. That puts it up to our foreman, when we once determine what percentage of bond we are

getting the best results from, it is putting it up to him to maintain it there day by day. That is my view.

Dr. Moldenke.—I still cannot help asking you to be a little cautious and careful. You have heard the opinions of Moline, Chicago, etc., that that sand is very good. Come to the East and try this method and you may find it a little different; so be a little cautious in saying this method is a good test for the bond of sand. I think it is a good test for the grain of the sand, but the bond is different; you may have a very good sand around here but we in the East have some very poor sand.

Chairman R. A. Bull.—We have appreciated expressions of endorsement of what, in the opinion of the gentlemen who have spoken, are without doubt very sincere tributes to the method advocated by Mr. Smith, and it is gratifying. We might have expressions from people who have found difficulty, for instance, in ascertaining the bonding value by the use of the same method. This is the place where we ought to interchange these opinions and it would be perfectly appropriate for a full exposition of this.

N. K. B. Patch.—I think that we are laboring under a little misunderstanding. It seems to me that Mr. Smith has offered a very strict method of control that compares very favorably with the control of the modern foundry foreman in connection with the temperature of the metal, the average man who is pouring metal every day gets the temperature of the metal very accurately and the proper temperature is maintained thereby, but we have to check him up occasionally with more accurate tools, and for that reason we use the pyrometer, and by keeping those pyrometers well calibrated so that they are accurate, we check up the practical man in his temperatures. That, it seems to me, is the function of the method laid down by the committee to revise the methods of the practical man, to give us the scientific methods that will check up with the practical man's yardstick. Both the yardstick and the methods of the scientific experts are advisable

and necessary. In our daily routine we must have the practical man's methods, but those methods must be checked up regularly and periodically by the scientific method which is laid down by the committee.

R. J. Doty.—I hope I am a practical man; I consider myself such, but I am also perhaps a little bit theoretical and perhaps a little scientific. In our plant we have, for more than two years, been testing our sands for cohesiveness by this method, for grain size by yonder method and for permeability by a method similar to this, although not as good, moisture and volatile matter. We consider that that test is a very important part of our daily life, and it has become so important a part that our sand is controlled daily from the laboratory. Last December I had the privilege, and I esteem it a privilege; I did at that time and do still, of listening to Mr. Smith describe and demonstrate his test. I returned to Milwaukee immediately, procured the necessary appliances and started running Mr. Smith's test in connection with our own. I consider that this test can be used as a control test, and it is as such that perhaps we use it. I do not want to be quite as strong as to say it is a control test, but we use it because we can see visually the change from day to day on our sand. I think that is what you claim, Mr. Smith, and that is the way we use it in our own shop. Mr. Smith's test in a very few minutes and in a very pretty manner, shows the separation of grain and fine material. That test shows how the percentage of grain to fine material varies and will permit a man, I am sure, to regulate his mixture so as to correct the variation and bring it back to his standard. This test separates grains and fines; all the fine material is not bond; part of it is bond; and we have conducted some experiments at our plant to ascertain if that test is or is not a measure of bond, and so far we feel that it is not. I happen to have with me, because it was handed to me before I left Milwaukee, the latest reports from our laboratory in which we had run some tests. We have here four sands; I will not mention the names. According to Mr. Smith's test, the bond in one is 8.7 per cent. Accord-

ing to another, the bond is 35.1 per cent; a third, 40½ per cent; a fourth, 48½ per cent; if that fine material is bond, then the fourth sand should be approximately six times as strong as the first. I think you will agree with me on that. We took those same sands and ran the cohesiveness or bonding strength test as recommended by the committee, and we got for those cohesiveness values, 115, 162.3, 190.9 and 279. There are two ratios as shown by the two tests. Now, as a means of comparing one with the other, we called the bond of the weakest sand unity and divided the bond of each of the other sands by that value. Using that weakest sand as unity, the bonding factors of the sand as expressed by Mr. Smith's test are, 1, 4.06, 4.88 and 5.56. In the same manner, considering the weaker sand as unity and expressing the bonding values of the other sands as a factor, we get 1, 1.41, 1.65 and 2.42, by testing as recommended by committee. By the Smith test, if you call the fine material bond, one sand should be 5½ times as strong as the other. By the recommended bonding strength test which is a direct physical test measuring a property of a sand, we find that that strongest sand is 2.42 times as strong as the other. In other words, all of the material which appears in the bond factor of the Smith test is not bonding material. Feeling, Mr. Smith and gentlemen, strongly as I do, the great help which Mr. Smith's test will be to the foundryman who has never had any means of controlling or watching the change in his heap sand or his facing sand from day to day; feeling as I do that every one of these tests is as reliable as it is possible to make a test on such a crude material as sand, I am bound to state that I do not feel that the Smith test is a measure of bond. I do not feel that those tests do those things which we claim for them, but I want to tell you about this because I like to have you all go away feeling as I do, that anything which tends to watch control, regulate the condition of our heap sand and of our facing, is well worth while, and I believe that if any organization in any little bit of a shop will carry out the Eugene Smith test each day, they will see the change in their sand and they will

be able to regulate that change, but I do not believe they can measure the amount of bond, the amount of permeability in their sand by that test.

H. F. Davis.—As raw material inspector in our plant I might say that I have a vast number of different materials to test out, sometimes several carloads of different materials come in at the same time, and on such occasions it is quite difficult to have a speedy test to get at just what you want. I have had to work out on many occasions, simple tests for various commodities. I might say, I trust Mr. Smith will forgive me, that I never heard of his test before, but I might say that I have been using that test for the last three years.

Mr. Beeter.—Outside of Mr. Smith's method of separating the so-called bonding material, I find that when the grains in the lower end of this tube are still covered with the active clay substance, that the water does not wash all the clay substance from the sand grains, and the clay substance that will remain on the sand grains is some of the best bonding material you have in the sand. That may be considered as one of the weak points. Another point is this, that in the laboratory method, it does not separate the grain sizes into groups or regions of a uniform size; some of the sand grains that are small if entrapped under the microscope would show, when samples are taken from the different regions, that some of the fine silt is still under the lower regions of the coarse grains. The method of Mr. Smith does show the proportion of the sand grains to an extent. This may be called a factor, one of the factors of permeability, but permeability is controlled by many factors, and some of the most important of those are the nature of the clay coating on the sand grains which the method does not tell us or indicate, the amount of moisture contained in that sand which has an effect on the permeability. We can, with the committee method of permeability testing, test our sand just in the same condition as it is practically produced, as it is on the floor, therefore if we can test our permeability as the sands are on the floor, we get a proper venting quality. Another factor of per-

meability is the grain size or the shape, I should say, whether they are angular or round, and I do not see how this method of Mr. Smith will indicate that factor of permeability.

R. F. Harrington.—I believe that we can continue to argue the merits of the one method as compared to the other from now until the middle of next week, but I think that we can all take this paper of Mr. Smith, and if you will just turn to page 6, at the bottom of the page, and continue on to page 7 and consider some of these very pertinent questions that Mr. Smith asks, I am sure that it will be well worth our while; for example, the relation of our losses to sand conditions. How to avoid these losses. How to select sand suitable to the class of product desired. How to anticipate our loss by reducing the source. He goes on and enumerates very pertinent questions and I believe that Mr. Smith does not, for one minute, claim that his step will give an answer to all these questions, but I do believe that what we want to get out of this meeting is the fact that Mr. Smith in his paper has asked very, very live questions and we must answer some of those questions if we want to reduce our foundry losses.

Mr. Hull.—I happened to be at the meeting at Moline when Mr. Smith was there, and I want to say this about his method, that the time we shake this bottle has something to do with it, too, the amount of separation you get, how effectively it is watched. I took the same samples of sand and got different results. I took some denatured alcohol and tried it out and got a better result that way; it seemed to cleanse the clay more thoroughly. I got 10 to 15 per cent more bond on this particular sample of sand than I did with water, and also I took some caustic soda—I used caustic soda on this same brand of sand, and I got 20 per cent more bond than I did with water alone. Whether that is due to more thorough washing or whether the soda had an inflating effect on this fine silt, is a question I am unable to answer.

E. Smith.—I would like to answer one or two of them.

The gentleman who last spoke is usurping the duties of the chemist when he starts to introducing alkalis or alcohol. The gentleman that spoke before him struck on a subject which is delicate with me because I was not sure of myself, I did not enter it in the paper, but I will read it to you with this reservation, that there is nothing in my mind that is settled on it. The word "silt"—he used it—I do not know how we both struck the same word, but here is a little memorandum of mine, typewritten in my book; it is a short one and I want to read it to you. "Silt; this term is applied to a portion of the silica content as divided into more than two parts by the vibratory method, and is usually seen in a small vein of extremely fine sand over that which is the representative grain or silica content, and I should say is separable by water." This is my own private memorandum. This fine material would undoubtedly fill in between the larger grains, and if in excess would destroy the permeability of the sand for escape of gases. Where the danger line would lay has not yet been determined. This silt or finer material would possibly cause trouble in another direction, which also has not yet been thoroughly investigated; that is in the manufacture of cylinders, valves, fittings or other castings which are subject to high pressures and require tests for leakage, in the flow of molten metal into the mold, particularly where the force of the flow is present, it is very apt to wash out this finer material from between the heavier grains, leaving a fine marking of cut sand showing in the direction of the flow of the metal. This washed away material, taking the form of a fine dust, would undoubtedly mix with the iron and lodge on the underneath side of the core, if used, and in the angles, forming a porous honeycombed mixture of iron and sand, which under ordinary observation of the leakage would be attributed to shrinkage. There are cases where a sand condition might cause the foundryman to attribute it to metal. The young man that spoke there apparently almost quoted the same words that I have in the paper, only I did not care to give it out. I give it to you now for what it is

worth. I have not gone far enough to know whether there is anything in it or not, so I do not say that I claim it is reliable. Use the vibratory test and examine it yourself.

Mr. Newhouse.—There was a time when the foundryman thought it was sufficient to judge of iron by fracture, and I think this method of judging sand compares to that. When you have the same sand, it is undoubtedly of value, but when you have an entirely different sand, it is of no value whatever. That is my view.

J. D. Stoddard.—For over 20 years or 25 years, I have been making use of a very similar method to that which Mr. Smith has described. He may not know it, but I am a member of this research committee. I have not been very active. It is impossible for me to attend the meetings, but I am heartily in favor of the work they are doing; I believe it is making for progress along the line of study in molding sands for foundry use, but I must say, for the benefit of Mr. Smith and what he has given us here today, that his test is a mighty valuable and practical test for any foundryman to adopt, and I hope the research committee will recognize its value. I know from experience in selecting the better sands or the best sand among two or more samples submitted to me, that without failure we have been able to indicate to our customers the sand which will best suit their purpose. It is sometimes necessary, as Dr. Moldenke has said, for us to have a sample of the sand which is of known quality and of satisfactory quality, in order to compare the sample under test with that sample in regard to the amount of fine and the amount of grain, but by using that simple test which can be made in a few minutes, the foundryman may know in advance, with considerable surety, that the sand he has selected from several offered him for purchase, is best suited for his use.

The Cohesiveness Test of Foundry Sands*

By H. Ries and C. M. Nevin, Ithaca, N. Y.

It is a well recognized fact that the cohesiveness or bonding power of a foundry sand is an important property, and such being the case it is highly desirable to have some accurate method of determining this property and expressing its value numerically if possible.

In some recent articles in the *Foundry*,** R. J. Doty has discussed in some detail two methods for testing cohesiveness, viz. the tensile strength test, and the bar test. The latter, and more satisfactory method, which has been developed by him, is found to give the best results.

It seems to the writers that this is indeed a simple test, easy to operate, and productive of very uniform results.

In view of the fact however that the method may be used by different persons and for testing many different sands, the test should of course be carried out under uniform conditions so as to give results which are safely comparable.

There are also certain factors which affect the results obtained, but which if taken into consideration in making the test need give no trouble.

The factors, which it is the purpose of this paper to consider include: 1. Method of compaction, 2. Degree of compaction of different sands, 3. Effect of water content, and 4. Method of calculating and expressing the results.

Method of Compaction

It is obvious that if different operators are to use this test the sand should be packed, into the bar mold under

*Based on results obtained from an investigation conducted at the Molding Sand Laboratory, Cornell University.

**_Foundry_, Jan. 1 and 15, 1923.

exactly similar conditions. While hammering the sand in with a mallet might do very well for a daily foundry control test, different persons testing different sands might not

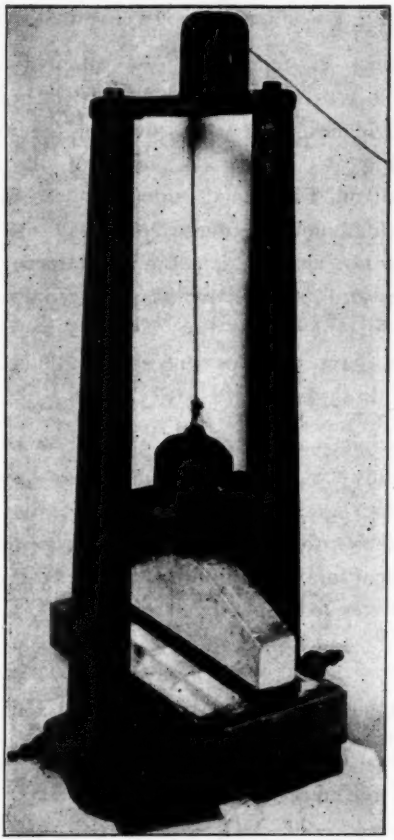

FIG. 1

pack the sand in to the mold with the same strength of blow, and since, as will be shown later, the energy of the blow is of importance, some means should be devised to use a measureable force in order to get results that are

strictly comparable. It seemed to the writers that instead of driving the top of the mold down with a hammer, it would be better to drive it down with a known weight, dropped from a given height, a given number of times.

After some experimenting we adopted a 20 pound weight which was dropped between two guides, from a height of 16 inches, on to the cover of the mold box*, as shown in Fig. 1. Since the head of the weight was but three and one-half inches square it was felt that striking such a small portion of the surface of the cover of the mold, might not evenly distribute the force of the blow through the sand. Consequently a hardwood truss like that shown in the figure was fastened to the mold box cover. This gave excellent results and secured uniform compaction throughout the bar.

After trying compaction of the sand with a varying number of blows of the drop weight, 6 drops were adopted for the reason that a less number did not give sufficient coherence to make the breaks of the bar, when tested, uniform, and because a large number tended to give a fictitious cohesiveness to even a nearly dry sand.

Degree of Compaction of Different Sands

As first suggested by Mr. Doty, all bars were to be hammered to a thickness of one inch, but when we came to experiment with different sands it was found that the energy or force necessary to compact a 1000 gram sample of sand to a bar one inch thick varied with the sand as well as with the water content. By keeping the compacting energy constant the resulting sand bar will vary in thickness depending on the particular sand and on its water content, as shown by the following figures:

*For construction of the mold see articles by R. J. Doty, *Foundry*, Jan. 1 and 15. 1923.

Sand	Per cent Water	Thickness of bar in inches
Albany selected	6	1.20
Albany No. 0	6	1.05
Millville	6	1.15
Lumberton	6	1.07
Virginia	6	1.04
Virginia	4	1.10
Virginia	6	1.05
Virginia	8	1.03
Virginia	10	1.00

Considering the last set of figures it is evident that it would take much more force to drive the sand with 4 per cent water down to one inch than to drive it to the same thickness when it has 10 per cent of water.

The same applies to an Albany selected sand and a Lumberton sand, it requiring much more force to compact the Albany to the same thickness as the Lumberton.

It might be thought that a small difference of 0.10 inch is negligible, but it is really a large factor in the strength of the sand, and sometimes amounts to an increase of over 30 per cent in the strength of the bar, because of the additional compaction necessary to drive it to one inch as shown below on two sets of tests made on the same sand with the same water content.

No. of drops of weight	6	25
Thickness of bar in inches	1.15	1.05
Average weight of broken pieces in grams	203	240
Weight recalculated to one inch	176	235

These figures also show the increased compaction obtained by 25 blows as compared with 6, and also accounts for the greater strength of the bar which has been given the greater number of blows.

Relation of Thickness of Bar to Strength

Since a thicker bar of a given sand will show greater strength, it will be recognized that bars of different sands can not be compared unless they either have the same thickness, or some correction factor can be used to make allowance for the difference in thickness.

Two possible methods of adjustment suggest themselves. These are, (a) shaving down the bar to one inch and (b) applying a correction factor.

We have not tried the former method, because it seems to involve certain objections aside from entailing more work. The possible objections are, 1. injury to the bar in shaving by setting up flow strains; 2. difficulty in so treating sands that have very coarse grains; and 3. if the bar has a greater density at the top, it would remove the strongest part of the bar.

We understand that one investigator has used a special device for shaving off the bar before it is removed from the mold, and that it has worked fairly well.

A simpler method in our opinion is to reduce all the pieces which break off in testing, to a theoretic one inch basis by dividing the weight of each piece by its thickness in inches.

Of course this would not be strictly accurate mathematically, but it is thought that within the ordinary limits of the cohesiveness test, it would be sufficiently close.

In order to test out this theory, varying amounts of the same sand, uniformly tempered with the same water content, were molded with the usual six blows. Any difference in length and weight of the broken fragments should be due solely to the difference in the thickness.

The following figures will serve to bring out the point:

Weight of sample in grams	Thickness of bar in inches	Average weight of break in grams	Recalculated to one inch thickness
		Sample 28	
800	.93	151	162
850	.98	157	160
925	1.07	183	173
1000	1.15	203	176
		Sample 24	
900	.95	300	316
950	1.00	320	320
1000	1.03	322	312
1050	1.10	335	305
1100	1.20	350	305

These examples cover the usual limits of thickness that will be found and it should be noticed that the varia-

tion in No. 28 before correction for thickness is 34 per cent, while after correction it is 8.6 per cent. In No. 24 the greatest variation in the breaks after correction is 4.6 per cent, and it would mean that these differences are really in keeping with the accuracy of the entire test.

As might be expected also, the strengh as measured increases with the thickness of the bar.

Correction for Water Content

Even when we have the strength of the bars recalculated to one inch, there may still be a difference in the water content, and consequently for accurate comparison of different sands, it seems to us that they should be compared on a dry sand basis.

Effect of Water Content on Compaction

The object of the cohesiveness test is to show not only the relative cohesiveness of various sands but to also indicate the water content which will develop the best degree or optimum of cohesiveness.

By using therefore uniform energy in compacting, measuring the thickness of the bar, recalculating the strength as expressed by weight of broken pieces to one inch, and expressing the result on a dry sand basis, a "real" cohesiveness figure is obtained that will definitely show the variation in cohesiveness with different per cents of water and between different sands.

We quote some examples of this below, and have also expressed them graphically in Fig. 2.

Virginia Sand Sample 24

Per cent Water	Thickness in inches	Weight of pieces in grams	Recalculated to one inch	Recalculated to dry sand basis
6	1.05	315	300	282
8	1.03	239	232	213
10	1.00	202	202	182
		Selected Albany		
4	1.18	225	191	183
6	1.19	260	220	207
7	1.15	280	243	226
8	1.12	268	239	221

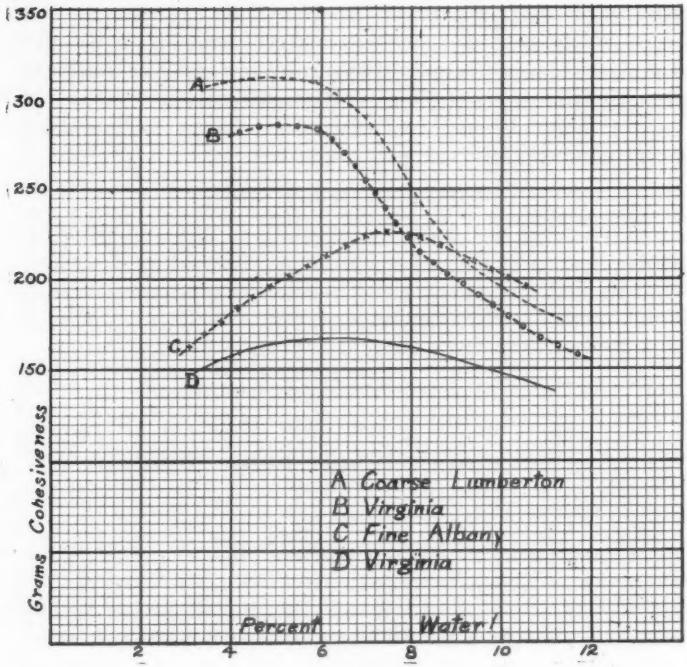

FIG. 2

These figures show firstly that the degree of compaction varies with the water content, and secondly that No. 24 develops its optimum cohesiveness with 6 per cent of water, while the Albany selected showed it with 7 per cent.

We also wish to call attention to the fact that a slight variation in the water content may cause appreciable variation in cohesiveness.

We have also tested some sands which differ from the above in showing comparatively little change in cohesiveness with a change of several per cent in their water content.

Water per cent	Thickness of bar in inches	Average weight in grams of pieces	Recalculated to one inch	Recalculated on dry sand basis
		Coarse Lumberton Sand		
4.5	1.08	356	329	too dry
5.3	1.09	357	328	311
5.8	1.08	357	331	312
6.8	1.05	326	310	289
8.6	1.02	257	252	230
10.3	1.00	213	213	191
		Virginia Sand		
4	1.17	192	164	158
6	1.17	210	179	169
8	1.15	203	176	162
10	1.15	...	too wet	...

Daily Foundry Control

It may be argued that the method of calculating the cohesiveness on a dry sand basis, and making corrections for both the thickness of the bar and the water content, involves unnecessary labor, but these recalculations are perhaps not in all cases obligatory, and should be employed only when different or unknown sands are being compared.

Where the same sand is being used in the foundry, and checks are run simply for daily control it would seem that the recalculation for thickness or even moisture content could be omitted.

Accuracy of Results

After making numerous tests of cohesiveness the writers have found that with ordinary care a very small variation is shown by different bars of the same sand. Care is always taken to see that the sand is thoroughly mixed before testing, for if not one must expect irregular results. If the first and last breaks of the bar show much variation from the others they should be rejected, but we have found that in most cases the first break can be averaged in with the others.

Considerable attention has been given by several investigators to the rate of propulsion of the bar, and the consensus of opinion is that the rate should be slow, although so

far as our personal experience goes, the effect of differing speeds seems to be more noticeable on coarse sands than on fine ones.

Brass Molding Sand Reclamation and Conservation Experiments

F. L. Wolf and A. A. Grubb, Mansfield, O.

The work done on this subject by the Ohio Brass Company has had two objects in view, namely first to reclaim the partially burnt or worn out sand regularly discarded from our brass foundry floor, and secondly to find if possible a local (Ohio) sand suitable as a substitute for Albany sands for brass molding. We were rather late in getting the tests under way due to preliminary work necessary to develop and acquaint ourselves with the permeability, dye absorption and other tests which were to serve as guides in the work. These tests were and are yet in state of development so a considerable amount of time had to be spent on them before we could even begin to intelligently interpret their results. Without these tests we would have been working very much in the dark.

H. S. Simpson of the National Engineering Co., of Chicago, kindly loaned the use of a muller type mixer of about two cubic feet capacity for use in the experiments. This was set up in the foundry and is being used for mixing sands.

Laboratory Tests

Following is a brief outline of the laboratory tests employed in our experiments.

Fineness. A Ro-tap shaker manufactured by W. S. Tyler Co., of Cleveland and a set of 8-inch screens are used. The screens are of the following mesh: 10, 20, 28, 35, 48, 65, 100, 150 and 200. Three 5/16-inch steel balls are placed on each screen, a 100 gram dry sample is placed on the upper screen and the shaker operated 20 minutes. Average fineness is calculated by multiplying the weight of sand which passes through each screen by the mesh of that screen, adding the products and dividing by the weight of the sample, 100 grams.

Bond. The apparatus and method as originally described by J. R. Doty* was used for a number of the determinations. The weights of the pieces of molding sand broken off as the

*Transactions A. F. A. vol. 30 p. 796-822.

standard core was pushed over the edge of a glass plate were taken as a measure of bond.

PERMEABILITY. A core of sand five-eights inch in diameter and two and three-quarter inches long is rammed up in a brass tube according to a standard method. An aspirator is used to draw air through this core under a standard pressure. The time required for the passage of a standard volume of air is taken as a measure of the permeability of the sand. It is, more correctly speaking, inversely proportional to the permeability, the longer time figures indicating tighter sand.

DYE ADSORPTION. The method described by H. B. Hanley* is employed with a few changes. Weaker dye solutions are used and measurements are made with aid of a Bausch and Lomb colorimeter. Results are expressed in percentages of the original dry sample.

MOISTURE. Moisture tests are made by drying a sample at about 220 degrees Fahr., and calculating loss of weight as a percentage of the original damp weight.

Refuse Sand

Each morning the floor of the brass foundry is swept to get rid of the burnt sand which clings to the castings as they are shaken out of the molds but which shakes off more or less as the gates are gathered up for removal to the knockout bench or sprue cutters. These sweepings contain pieces of cores, core sand, brass spillings, core nails and wires, burnt molding sand and some molding sand that is only partially burned. They are first put over a one-inch screen which takes out most of the cores and the large pieces of brass. The brass is hand picked and returned to the foundry while the cores are discarded. The material which passes through the one-inch screen falls on an eight-mesh screen. This takes out the core wires and nails and the smaller brass spillings. The nails and wires are removed by means of a magnetic separator and the brass is remelted. The sand which passes the eight-mesh riddle has for the most part been discarded in the past; it is this material which we are now attempting to recover for use on our molding floors. A small amount of it has been used when new molding floors were started, mixing it about half and half with Albany No. 1. Attempts have also been made to return it to the sand heaps but this has not proven satisfactory.

*Committee Report before 1923 Cleveland meeting A. F. A.

The Problem

Attempts to use burnt or worn out sand usually result in complaint on the molder's part that the sand lacks bond and dries out too rapidly. Evidently heat from the molten metal destroys bond and changes the water absorbing and retaining properties of the sand. Our problem, then, was to find means of restoring bond to the burnt sand and also restoring its adsorptive properties.

There is at present but little available information regarding the nature of the bond or bonding material in sand. The writer is of the opinion that that property of sand which the foundryman recognizes as bond is determined largely by the size of the particles and perhaps in a less degree by the nature of the substance composing those particles. It is quite likely, too, that it is the size and nature of those particles which are smaller than 270 mesh (0.053 millimeter diameter) that have most influence on bond; the smaller these particles are, the more bonding value they have. As to the nature of the substance, it is probable that it consists largely of silicon, aluminum and iron oxides and their hydrates in a more or less colloidal condition and small quantities of organic matter. The hydrates absorb water more readily than do the oxides and are, therefore, better bonding agents. At the temperature of molten metal the organic matter is burned out, the hydrates are converted to oxides and many of the small particles are agglomerated into larger masses; these changes tend to decrease bond. If the above theory is correct and there is considerable evidence to support it, then our main problems in reclaiming burned sand may be outlined as follows:

(1) The agglomerated particles should be defloculated by mechanical or chemical means.

(2) The oxides of silicon, aluminum and iron should be at least partially converted into hydrates if possible. This will involve chemical processes.

(3) New bonding material should be added in the shape of clay or highly bonded sand.

The work done thus far by the Ohio Brass Company has had to do largely with this last phase of the problem. No attempt has been made to use chemical reagents in treatment of the sand; we have tried to restore the properties by additions of higher bonded sand only. The fineness, dye adsorption, moisture, bond and permeability tests as outlined above

were employed as means of getting numerical data on the condition of the sand heaps.

Experiments

With view to determining the characteristics of used molding sand that was working satisfactorily, tests were made on samples from several floors. Samples of Albany No. 1 and two samples of refuse sand were also examined. The results of these tests are given in Table 1.

The results show that the refuse sand is a little coarser than new or used sand, is lower in bond and more permeable. The dye adsorption value also appears to decrease with use. The second sample of refuse sand had a fairly high dye adsorption value so it was decided that a trial would be made with this sand on a molding floor. The sand was put through a Simpson muller type mixer to mix it with water and give it a uniform temper. It was then put on a floor and used for two days by one of our best molders. He found that it rammed up well and produced good castings but the heap dried out rapidly and had to be cut more frequently. It was then tested showing an average fineness of 113.1 and dye adsorption of 0.064.

Table 1

	Average fineness	Dye adsorption	Moisture	Bond	Permeability
Floor 1	128.3	0.062	7.47	163	186
Floor 2	122.0	0.073	6.60	152	182
Floor 3	123.1	0.066	5.46	157	176
Albany No. 1	124.3	0.081	7.98	176	159
Refuse sand	116.2	0.052	5.60	145	144
Refuse sand	115.9	0.063	5.20	144	140

Evidently there was a considerable quantity of core sand in the heap. While the dye adsorption value was fairly high, the tendency to dry out together with the low cohesiveness and the low permeability number indicated the need of finer sand and bonding material. Tests had been made on several grades of molding sand that were on hand; the results showed nearly all Ohio molding sands were very high in dye adsorption value, ranging from 0.120 to 0.900 per cent. One sand, Nickelplate No. 1, had a value as low as 0.109 per cent and an average fineness of 158. Calculations showed that a mixture of three parts refuse sand and one part Nickelplate No. 1 should give an average fineness of 124 and an adsorption value of 0.075 per cent. The mixture was accomplished in the Simpson mill, running each batch about ten minutes;

tests then gave an average fineness of 125 and adsorption value of 0.073 per cent. Upon trial the heap worked well in every respect, produced good castings and held its temper.

Upon working the first experimental heap three days, results were so satisfactory that we determined to start another floor with the same kind of sand. This was done on November 18, 1922.

During the first few weeks tests were made periodically for fineness and dye adsorption; we then extended them to

Table 2

EXPERIMENTAL HEAP NO. 1

Date	Fineness	Dye Ads.	Mois.	Cohes.	Perm.
11-14-22	126	0.073	...	...	...
11-17	130	0.073	...	...	...
11-21	124	0.070	...	...	...
11-24	122	0.070	...	...	...
12-1	126	0.072	6.49	...	181
12-9	122	0.065	...	...	...
12-15	119	0.063	...	...	...
12-22	120	0.068	5.87	158	179
1-4-23	119	0.067	6.10	161	180
1-12	118	0.061	5.02	138	195
1-19	118	0.059	6.85	138	209
1-27	123	0.075	4.80	...	...
2-2	129	0.085	7.70	143	244
2-8	126	0.079	7.60	145	261
2-16	122	0.069	5.65	148	216
2-23	122	0.071	6.30	150	207
3-1	124	0.061	6.22	144	205
3-8	122	0.063	5.27	136	201
3-16	118	0.060	5.50	140	186
3-23	116	0.063	5.14	147	186
3-30	119	0.066	6.37	152	185
4-6	122	0.067	6.28	154	181
4-13	128	0.071	6.50	148	174
4-20	123	0.072	6.16	152	187

EXPERIMENTAL HEAP NO. 2

11-18-22	123	0.071	...	...	...
11-21	120	0.069	...	...	...
11-24	123	0.064	...	...	...
12-1	121	0.063	6.22	...	168
12-9	121	0.063	...	...	...
12-15	120	0.061	...	...	...
12-22	121	0.060	6.71	156	199
1-4-23	129	0.063	5.17	151	179
1-12	123	0.064	6.65	165	218
1-19	119	0.066	5.75	155	206
1-27	124	0.069	5.70	...	210
2-2	122	0.077	6.60	136	226
2-8	124	0.074	7.54	145	279
2-16	109	0.063	6.20	140	180
2-23	119	0.067	6.10	142	200
3-1	122	0.065	6.35	143	193
3-8	119	0.063	5.88	139	194
3-16	127	0.061	5.41	147	185
3-23	112	0.063	5.00	157	171
3-30	133	0.068	6.13	159	190
4-6	123	0.064	6.22	161	195
4-13	132	0.069	7.11	146	171
4-20	124	....	6.11	143	199

moisture content, cohesiveness and permeability. Prior to February 23, 1923 these tests were made on the sand as received and inasmuch as the moisture content varied, the

cohesiveness and permeability, which depend to a certain extent on the moisture content, are not comparable. Since this date we have made the tests on samples containing 6 per cent moisture. Table 2 gives the results of test on the two experimental heaps.

Additions of reclaimed sand, three parts refuse sand and one part Nickelplate No. 1, mixed in a muller, were made at the rate of about two and a quarter wheelbarrow loads (450 pounds) per week during the early part of the test. The molders reported that the sand worked well and losses in castings were low until early in February when losses due to "blows" began to creep up. The permeability and dye adsorption figures were also rising so we cut down on the new molding sand. The bin of sand supposed to be Nickelplate was sampled and tested; it was found to be finer than Nickelplate and higher in dye adsorption value. A car of higher bonded sand had been dumped into this bin by mistake. We then resumed the use of Nickelplate for bonding material and found that the proportion of three parts refuse sand and one part Nickelplate worked out very well.

Recently, since April 1, we have had just a little objection from the molders about the sand failing to wet down properly. This is noticeable late in the week and immediately before the weekly additions are made. These additions apparently remedy it for the time being. Tests for fineness, dye adsorption, cohesiveness and permeability have thus far failed to give any information on this condition. It is possible that the sand heaps are accumulating a little larger proportion of agglomerated or dehydrated material, largely oxides, which do not take up water readily. We hope to investigate this phenomenon more thoroughly in the future and possibly try to rejuvenate such sand by treatment with certain chemical reagents as has been suggested by H. B. Hanley and R. J. Doty of the joint committee on molding sand research.

Conclusions

It is impossible to draw definite conclusions at the present time. Thus far our experiments seem to indicate that it is possible to add a sand high in bonding material to sand which is partially burned out and obtain a product that works well on our class of work. Ohio sands are as a rule high in bonding material so, for this section of the country, any reclamation of refuse sand that can be accomplished by the method outlined above effects a marked saving, not only in refuse sand but also in freight charges on the new

sand necessary to replace that which is lost from the heaps. Albany sand costs $5.15 per ton delivered at Mansfield while the recovered sand composed of three parts refuse sand and one part Nickelplate costs about $0.85 per ton mixed and ready for use, a difference of $4.30 per ton.

It remains to be seen whether there will be a gradual accumulation of burned out material in the heaps due to the return of the refuse sand. No bad effects, other than a slight difference in tempering qualities, have shown up as yet but conditions have not been severe. The refuse sand contains quantities of Albany sand that are yet in good condition. The test will be more severe when we return to these experimental heaps their own refuse sand as we are expecting to do in the future.

Reclaiming Foundry Sand

By H. M. Lane, Detroit, Michigan

As the writer has been asked to give some of the facts concerning the experiments on sand reclamation run several years ago, the following account is of this work which had its beginning in the writer's metallurgical experience in trying to solve certain foundry difficulties which the owners felt convinced were due to metal conditions, but which by process of elimination were proved to be due to sand conditions.

We started studying the sand by making sieve tests, washing tests, chemical tests for bond, rational analyses, and microscopic examinations. The series of tests which led up to the first paper I wrote on the subject included work done in over 130 foundries. In a good many cases attempts were made to use old sand, and all of the devices that had been gotten up at that time that we could learn of for reclamation of sand were investigated. A chemical laboratory was eqtuipped to do organic chemistry and work was also done in many plants laboratories. For several years the writer maintained a laboratory in Cleveland, which was later moved to Detroit. Here it was developed into what was essentially an experimental foundry with capacity for doing practically anything that is done in the ordinary foundry. The equipment installed has been described in technical articles in the past.

One whole series of experiments were run on the reclamation of sand, and several hundred tons of sand was cleaned, returned to foundries and re-used. The writer had formerly had extensive experience in ore classification and concentration, and a brief study of the specific gravities present in the ingredients of molding sand showed that the old standard rule of classification and concentration by means of resorting to equally falling bodies, and then to size, was not close enough to effect a separation of certain undersirable elements, as for instance grains of limestone in sand, or other fusible ingredients.

A microscopic examination revealed the fact that waste sand contained a great many grains that were perfect, and common sense dictated that these were just as good for use in molding or for core sand as any other grains, provided nothing adhered to them to injure them, or to injure the bond used. The question was then how to separate the fine dust, burnt clay, and other deleterious material from the usable grains. It was evident that we could resort to either wet or dry processes.

Equipment Used

The laboratory was fitted out for a number of wet processes including a Capron washing barrel as then manufactured by the Osborn Mfg. Co., a vertical column agitator about 30 ft. high, a Dorr classifier, and several different styles of hydraulic classifiers. The hydraulic classifiers all worked on the principal of equal falling bodies, and by means of them it was possible to take out almost any grain size that was desired within very close limits, but it required careful adjustment of the equipment, and common sense indicated that anything of this kind would never be a success in the foundry.

From a wet separation standpoint the Dorr classifier gave the best results. In the case of sands that were pretty badly matted the Capron barrel was used for agitating the mass in water and separating the individual sand grains. Of course, in all cases any coarse lumps were given a preliminary crushing, and for this purpose we had a hammer crusher, and a pair of rolls. We also had two sizes of pan mills, but they were used mostly for rebonding sand, though experiments were made with them as crushers. We also had a special centrifugal crusher similar to a Sellars, but made on a very much larger scale, the runner disk being nearly 2 feet in diameter and the pins about ¾-inch in diameter. This, however, did not prove a success as a means of breaking up the lumps of sand, on account of the fact that it only had one whack at the sand as it went through.

The Dorr classifier gave a very good product particularly

in cleaning certain types of core sand and old steel foundry sand.

Problem Encountered in Wet Process of Separation

The biggest problem that we had to contend with in all wet processes was the subsequent drying of the sand to a point where it was in condition to be used in a mixture. An interesting fact is that both molding and core sand gains what might be called a priming coat or surface coat of material in use. Where oil sand cores are used this sometimes consists largely of condensed oil products all over the surface, much like varnish. In other cases it consists of a coat of fine carbon adhering very tightly to the surface. In some cases it is clay which has been bonded together and adheres to the surface. These films prevented the use of much of this sand for oil sand work on account of the fact that the films had a great affinity for oil, and would absorb it, but when the sands were to be used with water soluble binders such as molasses, waste sulphite liquor, starch, dextrin, and a wide variety of similar compounds, this film seemed to be advantageous, as it also did in connection with resin or pitch cores.

In drying the sand the most satisfactory drier we found was the steam pipe type used in the glass trade, though we had fair success with the stove type used in railroad shops for drying sand for locomotives. We experimented with hot plates with hoes or rakes for hoeing or raking the sand across them with fair success, but the capacity was small. A drum drier was fairly successful but if the sand was put in pretty wet it tended to bake pretty hard or stick to the buckets at the incoming end and prevent proper action at this part of the barrel or drum. A cascade drier with deflectors was not a success at all, and from one or two experiments tried it was evident that the vertical drop drier such as has been used for oxidizing sulphide of silver in one of the old processes in mining, but run at a lower temperature would be successful, but on the whole the steam drier pipe was the best there was not too much of a film on the sand. If there was enough film on the sand to make the

grains adhere under heat it was then necessary to use the drum.

Carefully conducted tests indicated that the cost of drying sand was almost always equal to the cost of cleaning, and sometimes was three times that of cleaning.

Dry Process Proves Most Economical

For this reason we found that the most economical cleaning methods were dry, and of all of the different methods experimented with the cascade cleaner worked out the best. In this the sand fell through a vertical shaft or tower with baffle plates which deflected the sand back and forth making it fall about 4 inches vertically from one baffle plate to another, and a current of air was drawn through the sand at right angles to these films of sand. By properly controlling the velocity of this current a very good sizing could be effected, and the sand could be cleaned within commercial limits, and at that time we believed it was cheaper to clean it in this way than it was to resort to any extensive scouring method. After the sand was cleaned the question was what to do with it.

The sand as it came to the laboratory represented a wide variety of products. Usually it consisted of a mixture of burnt core sand and burnt molding sand.

Where the core sand used was relatively fine, as for instance Michigan City sand, and the bank sands used in the automobile concerns we found that we could clean the sand and then rebond it with a fat clay, and make a good molding sand of it, or we could make a core sand for practically any binder except oil.

Several hundred tons of castings were made using in some cases cores of the cleaned sand, while in other cases the entire mold including the molding material and the cores were made of cleaned sand. Many tons of automobile cylinders were cast in molds, of which every pound of sand had been through the cleaning process, and not one of these castings was lost.

In the steel foundry practice, the surface which resulted from a mold made of cleaned sand was generally better than

the surface coming from one containing a large proportion of raw or new sand.

In one case a stationary engine frame weighing about a ton was made in a mold, of which every pound of sand was cleaned, and we got an excellent surface on the casting both inside and out. Fly wheels and small core castings were also made. Experiments were tried with soil pipe fittings and with standard water pipe.

Coke Sand With High Lime Content

One of the strangest sands that came into the laboratory was a core sand which had originally contained almost one-third of limestone pebbles, and most of this had been burned to quick line. Experiments were tried cleaning this both wet and dry. The sludge that came from our wet cleaners contained so much wet lime that it set into a hard cake, and when we tried the dry process we got a very large volume of exceedingly fine dust which could not be wholly taken out by means of a cyclone type dust arrester. Nevertheless the sand when cleaned proved just as good for the purpose for which it had been formerly used as raw sand from the bank, and the dry cleaning process cost about 30 cents a ton, while the sand at that time was costing people about $1.00 a ton.

Method of Operation

It may be of interest to state that every lot of sand which was received was tested first to see whether or not the lumps were broken down in connection with the cleaning process which we were to use, and if they were not the sand was crushed and riddled.

All of the apparatus used was grouped around a vertical shaft in which we had a bucket elevator running up some 40 odd feet, and the sand could be spouted from the top of this elevator to any one of the processes we wished to try.

For the wet process the sand from the elevator came down a chute into a receiving tank where it was agitated by jets of water and washed down a launder as a sludge. This sludge then entered whatever type of machine was to

be used for cleaning. The water used in cleaning was recirculated, provision having been made for a series of settling tanks for taking out the sludge, and in some cases when apparatus was set to take out coarse size only the sludge from the first tank was subsequently retreated for a different size.

In a number of cases we made up samples of sand from core sand or refuse received from one foundry, and used it in another foundry where it was more suitable as raw material than it would have been in the foundry from which it came.

Conclusions

The conclusion drawn from the tests run were that while some wet process for cleaning sand and sizing the same could be worked out successfully that the subsequent operation of drying and the difficulty of handling a wet process in cold weather, were a very serious handicap to this type of cleaning. It, however, appeared that a combination of wet and dry process might work out very well indeed for some foundries, with a subsequent blending of the wet and dry products in such a way as to take up the moisture. In this case the wet process would be the most thorough, but the dry process would be within commercial limits, and the two together might give a very good product. This is only true in the case of foundries having 40 to 50 tons or more per day of product to be cleaned, and in fact in some cases would not apply to plants having much less than 100 tons of waste.

Where a source of waste heat is available which can be drawn through some form of drier the cost of drying could be very greatly reduced, and one of these processes might become satisfactory.

Another objection to the wet process lies in the fact that all metal parts in a wet concentration plant are subject to quite rapid deterioration by rusting; for the sand scours off any protecting coating that can be put on the apparatus, and the frequent intervals during which the apparatus must stand idle result in corrosion.

Of the dry processes we decided that for most plants the proper thing to do was to lay out a successful crushing system with magnetic recovery of metals, in the case of metals which could be so separated, and the subsequent use of a cascade separator. In this case we would not attempt to recover every bit of the available sand, but would generally run the suction a little higher than theory indicated, in order to keep on the safe side. We would thus throw away some of the relatively fine material.

In making molding sands we experimented with quite a wide variety of clays including ball clays, wad clays, and other types of clay found in Ohio, Pennsylvania, Missouri and Illinois. In some cases clays that in themselves were not very refractory gave good results as bonding agents. In the case of a thoroughly cleaned sand which would be used as a molding sand we generally found it necessary to use 10 per cent of a good clay.

Additional Experiments

We experimented with some other organic materials for bonds, as for instance, flaxseed meal which is commonly known as oil meal, waste sulphite liquor, starch treated with an alkali, and various other means which had mainly for their object the formation of a colloidal coating on the sand grains which would cause them to adhere with a minimum stoppage of the vent passages.

We ran on to a good many curious things in the test. For instance, one lot of core sand, which came in to be cleaned, when examined under the microscope seemed to contain a lot of fine ashes, and these ashes had a very great affinity for oil, so that it was totally impossible to use the cleaned sand for oil sand cores. When we asked the foundryman if he was using ashes or cinders in his core mix he hotly denied it, but we found that he was using a fairly coarsely ground sea coal, and that this sea coal was rather high in ash, and the burning of the sea coal in the cores resulted in the formation of these particles, some of which were soft coke and some of which were true cinders, but these

particles stuck to the sand with exceeding tenacity and it seemed impossible to get them all out either by a wet or dry process.

Quite extensive experiments were also carried on with the use of peat as a binding agent. In this connection it was found that ordinary peat had very little bonding power and simply added a certain amount of organic matter. Certain peat swamps had contained a highly colloidal peat which contained an excellent bond, and in all cases the ash of this was found to be high in alumina. Further investigation showed that there was present a colloid which had been formed by the introduction of a very finely divided clay in the form of muddy water into the swamp during the formation of the peat.

The tests clearly indicated that on an average not less than 60 per cent of the waste product in the form of waste sand going out of the foundry can be reclaimed and re-used, and that ultimately this will be done at a decided profit. The most trouble comes in getting somebody to give the subject sufficiently careful control to keep the process within proper limits on the one hand, and on the other to get rid of the tendency of everybody in the plant to grab the cleaned sand as an alibi for every other possible trouble. No matter what went wrong in the plant it would all be blamed on that cleaned sand. In other words, before a process of this kind can be successful it must be sold to everyone in the organization including the molders, core makers, and those in charge of the work.

Report of Chairman of Joint Committee on Molding Sand Research

To the Members of the American Foundrymen's Association:

Your representatives on the Joint Committee on Molding Sand Research wish to report what they believe is considerable progress made since the Rochester convention of this association. It is expected of the one designated by the A. F. A. as chairman of this joint committee to make a brief resume of the last year's activities, and to offer such comments regarding work done and contemplated, as should have general consideration by you at this time. Detailed reports by the chairmen of the three subcommittees will focus your special attention to testing, conservation and reclamation, and the development of sand deposits heretofore unused for foundry purposes. Prior to the reference regarding these branches of the joint committee's work, it will be appropriate for the chairman to make some general remarks.

I beg to remind you that the inauguration of this joint investigation was made possible by $2500 contributed by Thomas and John Pangborn, and $1000 contributed by the National Engineering Co. to the A. F. A. for any useful purpose to be selected by the directors of the A. F. A. in advancing the foundry industry. This explanation was made at the 1922 A. F. A. convention, and is now repeated to indicate the benefit that can be derived in practical, scientific investigation from an insignificant number of cash contributions, when there are men sufficiently interested, of proper qualifications, who have the disposition to give freely of their time in co-operative efforts to advance the entire industry to which they belong, or in which by reason of occupation, they have some important economic or scientific interest. The activities of the joint committee on molding sand research present an illustration of one kind of co-operative effort that has no parallel in the history of the A. F. A., in the amount and purpose of the cash con-

tributions, and in the large number of men who joined in accepting the responsibility of doing the work for which the funds were set aside.

It is appropriate here to mention the pleasure afforded the joint committee, by the receipt a few weeks ago, of $1000, given by the American Foundry Equipment Co., to aid in continuing this investigation. This was unsolicited, as no campaign had been actually started to secure additional funds. Consideration of the executive committee has been given recently to the fact that practically all of the original sum of $4300 set aside for this research has been expended, in the 16 months during which we have actually been at work. Ways and means of securing funds to continue the investigation have been discussed, without reaching a stage of definite action, barring conferences with officers of the A. F. A., and preliminary steps taken by them to conditionally or temporarily finance the committee's work, in part, from the exhibition fund of the association. It would be very desirable if the joint research could be prosecuted without such assistance, or if funds so taken could be promptly returned. It will be possible to do this, if there is displayed the interest that ought to be taken in such work, by companies that will finally profit from such industrial research of tremendous significance to the foundry industry.

There are enough hard-headed business men on the executive and subcommittees of our joint committee to guarantee proper consideration of such matters as budgets. It has been impossible to look into the future far enough to determine with accuracy how much additional money we will need before the joint committee can consistently call its co-operative work completed. So far as we have been able to ascertain, $15,000 besides the original $4000, will provide for the energetic progress that we think ought to be made, and can be wisely made in this joint effort, during perhaps the next 12 months. Two research assistants are now in the committee's exclusive employ, one at the United States Bureau of Standards, the other at the plant of the Ohio Brass Co. Another such assistant is to be immediately put to work in the College of En-

gineering at Cornell University. In each case, the research assistant has free and complete access to equipment owned by the respective institution, and skillful direction on the ground, of a delegated member of the joint committee who gives much of his time to the work without compensation of any kind. Most of the work accomplished to date has been performed by the committee members themselves, often at considerable direct expense to their principals, and nearly always with heavy demands on the time of the individuals on the committees. With the probability of securing additional funds has come the conviction that we should make the work proceed more rapidly, and that we can do so without doubt, by supplementing the activities of the committee members, who have their own professional or business affairs to look after, and who must give them first consideration.

It would be misleading if I did not supplement what I have said regarding the few cash contributions, by reference to the way in which the foundry industry is indebted to those who have been members of the subcommittees. There are 24 gentlemen in this active class, selected from the total of 48 who constitute the entire joint committee. Those who are members of the latter, and are not members of its executive and subcommittees, serve in an advisory capacity. That they are qualified to do so may be judged from the fact that of the total membership of 48, 24 are foundrymen, 6 each from the gray iron, steel, malleable iron and nonferrous branches of the industry; 6 are sand producers, selected at the committee's request by the various associations of such producers; 10 are metallurgists, engineers or physicists; 5 are geologists; and 4 are refractory and ceramic experts. Representing as it does officially the American Foundrymen's Association, the National Research Council, the American Society for Testing Materials, the United States Bureau of Standards, the United States Bureau of Mines, the United States Geological Survey, and the Canadian Department of Mines, the joint committee has an exceptional personnel. Since half of its large membership has done the bulk of the work, with the assistance of outside agencies such as foundries and engineering depart-

ments of universities, it is hoped that foundrymen generally will give cordial support to these gentlemen who are giving freely of their time, without compensation, to the attempted solution of important phases of the molding sand problem.

The work accomplished to date has been mainly that of developing satisfactory methods of testing. At the beginning it was realized that a fundamental need existed for standardized methods for comparison and selection of molding sands. The committee, through its chairman, at the Rochester convention expressed the belief that suitable testing methods could be soon announced. Unanticipated difficulties in more widely applying methods that then seemed satisfactory, showed the necessity for revisions and refinements of important procedures in testing. The resulting volume of work thrust on the subcommittee on tests, and on other individuals who ably assisted, was very great, and consumed much time. In the present judgment of the subcommittee on tests, and that of the executive committee formed after submission of the several methods of tests to the entire membership of the joint committee, there should now be widely published for experimental broad use in as many foundries as possible during the next 12 months, three essential methods of tests, to determine bonding strength or cohesiveness, fineness and permeability. Two supplementary methods, one for making chemical analysis, the other for dye adsorption are submitted for similar trial. A method of sampling is tendered which will have its particular advantage in cases of dispute, or when it is important to secure a 'typical' sample of a fairly large lot of sand as shipped or delivered. These six methods have just been tentatively adopted for one year's trial, so that there may be obtained after broad experience, complete information as to their satisfactoriness or need for revision or substitution. For such purposes comments are earnestly requested, to be mailed at any time to the joint committee. It should be emphasized here that no member of the executive committee (which is responsible for the act of tentative adoption) feels that the methods now proposed are the final word on the subject. What is offered for trial for a year is the best that can now be submitted, after extended

consideration and many months of daily use in numerous foundries of widely differing character, following the experience of many years with many sands. The chairman hopes to see proper recognition accorded the results of the committee's faithful, tireless labor. That kind of work deserves the appreciation of foundrymen and sand producers, expressed by financial and moral support that is emphatic. It is up to you to accord it, and to thus indicate your confidence and your desire to have the work continue.

Respectfully submitted,

R. A. BULL, *Chairman,*

Joint Committee on Molding Sand Research.

Report of Sub-Committee on Geological Surveys

To the Members of the American Foundrymen's Association:

The function of the Subcommittee on Geological Surveys is to stimulate an investigation of the sand resources of the different states, in other words, to make a sand survey. There is a need for such a survey, because it is a well known fact that some of the deposits now being worked are not inexhaustible, and it is hoped that new deposits may be discovered either in regions where other supplies are now being worked, or in districts nearer to the different centers of consumption, because in some cases, as we all know, sand is being hauled a considerable distance and the freight rate is high. Indeed many foundrymen complain rather bitterly of the freight which they have to pay on sand. As a preliminary step to such a survey, a letter was prepared and distributed to the different state geologists through the secretary of the Association of State Geologists. This letter expressed the necessity for making a detailed sand survey in the different states. It also contained a brief description of the different types of sand that were needed, instructions for sampling sand deposits in the field, and a list of data which were to be collected at the different localities where sand samples were taken, the idea being of course to get as much information as we could regarding the sand resources of the different states.

At the time the first letter was sent out it was stated that the American Foundrymen's Association expected to be able to test the different samples that were collected by the state surveys, because it was known that most of these surveys did not possess any testing equipment, and it was furthermore known that their resources, as is often the case, due to the action of unsympathetic legislators, were rather limited, and that they were not in a position financially to make the detailed tests that were desired.

This letter met with a very favorable response from the different state geologists and the chairman of your subcommittee on geological surveys had an opportunity to meet with the state geologists, first at Amherst about a year ago, and again last October, in order to explain to them more fully just what was needed and to clear up, by personal explanation, any points of doubt that existed in their minds.

In the beginning of this year, it was found that the Foundrymen's Association would be able to carry out the necessary tests on the sand samples to be collected, and so a second circular letter was sent to the state geologists advising them of this fact, and they were furthermore asked at the time for a definite statement of their plans for the coming season or of any work which they had done in the past. Up to the present time we have received replies from a number of the states, and the most of them are very encouraging. Two states, Virginia and Maryland began field investigations of their sand resources in the summer of 1922, and in one case at least, Virginia, a number of samples were collected some of which seemed to be very promising. The geological survey of Virginia will continue its work in the field this summer, covering the rest of the state, and I believe the geological survey of Maryland, is also to continue its field work this coming season. The states which have written that they intend to begin field work during the coming season, collecting samples of sand from different parts of the state and also other necessary data concerning them are as follows: Alabama, Pennsylvania, New York, Missouri, North Carolina, Mississippi, Wisconsin, Indiana, Tennessee, California, New Jersey, Michigan, Illinois and North Dakota. That makes, I think, some 14 states from which we have heard definitely. We have not had any definite reply from the state of Ohio, which is an important one. It is hoped that we shall receive favorable replies from the other state geologists at a later date. Now in addition to the work in the United States, we also want to see work started on the other side of the boundary, in Canada, and last March, while in Montreal I had a meeting with the representatives of the Canadian bureau of mines and also the Canadian geological

survey. At that time the director of the mines branch, J. McLeish, assured me that his bureau would establish a testing plant where samples of Canadian materials could be tested. The representatives of the Canadian geological survey said that they hoped to be able to assign a man to field work in connection with the desired sand survey. There is some doubt, I am sorry to say, whether the geological survey will be able to carry out its part of the work, because their funds for this season are rather limited, but I still have hopes that they may see their way clear or find some means to support the demand in the field.

The samples which are collected by the state surveys in the United States will be sent to one of two points for testing. Part of them will be sent to the Bureau of Standards at Washington and part of them will be sent to the sand testing laboratory of the department of geology at Cornell University. We shall endeavor to divide the samples evenly, so that the two testing laboratories will have about the same amount of work to do. The results of the tests will be supplied to the state geologists; that is, each state geologist will receive the results of the tests on the samples from his state, and another copy will be supplied to the American Foundrymen's Association, so that they can both publish them, but it has been agreed and understood by the state surveys that before they finally publish their data, the manuscript will be submitted to the chairman of the joint committee, so that he can be sure that the data regarding these sands that a state survey may publish are all in correct shape.

One other point that I want to dwell upon for just a minute before I finish, is what I might call the relations of the foundryman to the state geologist. Of course the subcommittee has been trying to impress the state geologists with the importance and the great desirability of making these sand surveys, and a number of the state geologists are fully alive to the fact that this work is needed, but there are some of them who are not familiar with all the details of the foundry industry, who are not familiar with the importance of it as we see it, who say "Well, that is very nice, but I do not know just where I am

going to get the money." Now if the foundrymen in the different states will help us by getting in touch with their respective state geologists, I believe it will do a lot of good. Get into contact with your state geologist either by letter or personal interview, show him how important it is for you to obtain sand supplies near at hand and that by helping you find them he is not only benefiting the foundry industry, but also stimulating the sand industry. If the state geologist claims he has insufficient funds, see your representatives in the legislature and ask them to provide the funds for him to do the work.

Respectfully submitted,

H. RIES, *Chairman.*

Report of Sub-Committee on Conservation and Reclamation

To Members of the American Foundrymen's Association

The Subcommittee on Conservation and Reclamation, at the meeting which was held at Rochester during the month of June, 1922, decided that, before any active investigation on the subject in which this committee is interested, should be started, it would be well to send out a questionnaire to all of the foundries in this country and Canada. The object of this questionnaire was to determine just how much work had been done on this important subject and to learn what results had been obtained.

It was thought, the subject being of so much importance to the foundry industry, great interest would be shown and valuable ideas and information would be given to the committee.

During the month of August, 1922, 8777 questionnaires, as follows, were mailed:

To Gray Iron Foundries	4834
To Brass Foundries	1250
To Aluminum Foundries	2200
To Steel Foundries	250
To Malleable Iron Foundries	243
Total	8777

Each questionnaire carried a stamped, return addressed envelope. The address of the plants circularized were obtained from the Penton Publishing Foundry list. The expenses of printing and mailing the questionnaires, with the exception of those sent to the aluminum foundries, were paid by The Hunt-Spiller Mfg. Co., The Niles-Bement-Pond Co., The Eastern Malleable Iron Co., The Rhode Island Malleable Iron Co., The Ohio Steel Foundry Co. and The Ohio Brass Co.

The printing and mailing of the questionnaires sent to

the aluminum foundries was handled by the Bureau of Mines, under the direction of R. J. Anderson.

Of the 8777 questionnaires mailed, 1548 replies were received and of the replies received about 10 per cent contained information that could be considered of value.

It was indeed discouraging to the committee to learn that the foundry industry have such a lack of interest in this very vital and important subject of conservation and reclamation. It was evident from the questionnaires received that much cooperation could not be expected from the foundry industry as a whole, unless its interest were stimulated.

It seems as if the majority of present foundries are content in many respects to continue in their old rut of "rule of thumb." They are overlooking two of their most important working materials i.e., molding sand and core sand. In their foundries, these materials represent a considerable investment which ordinarily must be replaced from time to time. Instead of being reclaimed at a cost which would represent a saving over the purchase of new material, or even having a scrap value, it is discarded at an expense.

In spite of the lack of interest on the part of the foundrymen as shown by the returned questionnaires, we did obtain some results and it might be of interest to briefly give a summary of the replies received.

Summary of Data from Questionnaires

Albany molding sands are used by more nonferrous and malleable foundries than any other sand reported. Grades indicated as No. 00, No. 0 and No. 1 are preferred for nonferrous work. They are shipped as far west as Tacoma, Wash., for brass and as far as Milwaukee for malleable. Windsor Lock is also popular. Several foundries use sands imported from France and Belgium. Evidently it would be well worth while for foundrymen of the west and middle-west if satisfactory substitutes for Albany sands could be found in their sections of the country. A great deal of money now spent on freight could then be saved. It is true that nearly every sand dealer has a grade of sand which he claims is a substitute for

Albany, but practical trials and laboratory tests as a rule show that their physical properties are far different. There is, therefore, much to be done in the way of finding or compounding from local materials, satisfactory substitutes for these preferred sands.

Ottawa is by far the most popular steel molding sand. Portage and Massillon sands are also widely used.

Answers to a question regarding the testing of molding sands indicate that very little has been done along this line. About twenty per cent of the foundries answering the questionnaire report that they make tests of one kind or another, but give little or no data regarding their methods, nor do they give estimates of the value of these tests. Some of the steel foundries mention the use of chemical analyses, four or five make bond, fineness or permeability tests and one reports testing refractory properties by means of an acetylene torch. It is evident that most of the testing now being performed is done by "touch" or "feel," or by trial on the foundry floor.

Molding sand is as a rule stored under cover. The few foundries who reported that they stored their sand in the open either gave no reason for it or else said they had no available storage space. The reasons given for storing under cover may be summed up as follows: storage under cover prevents washing out the bond by rain, keeps the sand cleaner and allows it to dry out sufficiently on the surface so that it will not freeze in winter while yet retaining the moisture in the interior of the pile. This makes it easier to handle and leaves it in better shape for the molders.

Considerable difference of opinion exists as to the effect of damp aging on the working properties of sand. Some claim that it increases the bond and makes the sand work better while others claim that it shortens the life of sand, makes it rough and sticky and tends to produce pinholes in the castings; still others see no effect.

Most of the steel foundries use several kinds of facing, the greater number using two. A few use as high as eight or ten. Opinions differ as to the value of milling sand. Some

prefer to mill only long enough to thoroughly mix and no longer, for fear of closing up the sand, while others believe that long milling increases the bond. No data were given in support of either opinion.

In answer to the question "When losses in your production are attributed to sand causes, what are the main reasons for rejection?", some very interesting information was obtained from the nonferrous and malleable iron foundries. About 40 per cent of the trouble was reported as due to incorrect temper. About 25 per cent was attributed to the sand being too tight. Defective bond and burned out sand were also important causes of trouble. Practical test methods for controlling temper, openness, bond, etc., should be of great use to foundrymen in controlling these sources of trouble.

Questions regarding production brought out the following information: 137 nonferrous foundries reported a weekly production of 4,101,550 pounds of castings per week, an average of 29,939 pounds per foundry. Twenty-nine malleable plants reported a total of 7,058,000 pounds; an average of 256,000 pounds for each plant per week.

Seventy-four nonferrous foundries dispose of 544,175 pounds of refuse sand each week; this is an average of 7354 pounds for each foundry reporting. 16 malleable plants dispose of 1,593,600 pounds of refuse sand per week, an average of 99,600 pounds per plant. 55 steel plants report the disposal of 11,098,000 pounds of such material, an average of 201,790 pounds per plant. These 145 plants, then, dispose of a total of 6618 tons of refuse sand each week. The figures are enlightening in that they show the great loss of sand—sand for which we are hoping to develop methods of reclamation. They also show the relative importance of the reclamation problem to the steel, malleable and nonferrous foundries.

A few of the foundries report the use of some of their refuse sand in cores while several others, of the nonferrous group, sell it to refiners who reclaim the metallics or to fertilizer manufacturers for use in their products. Most of the sand, however, is hauled to the dump and no value is gotten

out of it except perhaps for filling. In fact, there is considerable cost attached to its disposal. 40 nonferrous foundries report cost figures ranging as high as $3.00 per ton and averaging $1.50 per ton. Among malleable foundries the cost of disposal is less, averaging about $0.78, probably on account of the greater quantities which they discard.

Use of Old Sand

The question "What proportion of new molding sand do you use with old sand in making up heaps?" brought forth answers ranging from 2 to 75 per cent. The average figure reported was about 22 per cent for nonferrous and 15 per cent for malleable foundries. No figures were obtained on steel or gray iron foundries.

Very little work has been done in the way of renovating used molding sand in a scientific way. Several report that they add new sand and then riddle or cut or both. Some add clay, organic binders or salt. Another reports that he uses a special machine that "rolls and sifts the mixture of old and new sand." Muller and paddle type mixers are in most general use. A few centrifugal machines are also reported.

Several nonferrous foundries are blending Albany with other sands some of which are local and seem to be getting good results. Several add coarse sand to their heaps to open them up. One foundry tried "bleached sand" with poor results. There seems to be a general opinion that the continual addition of clay to old steel sand has bad effects in that it tends to close up the sand and lowers the fusion point.

The following information was obtained regarding the proportion of new sand used to castings produced. 55 nonferrous foundries report that they are using an average of 260 pounds of new molding sand per ton of castings produced, the malleable foundries report 360 pounds and the steel foundries 1388 pounds of new sand per ton of castings.

Selection of Sand

In answer to the question as to what phase or phases of the work interested them, the selection, the preparation or the

conservation of sands, one hundred mentioned the selection, 55 mentioned preparation and 34 conservation of used sands. Of those mentioning selection, several said they needed methods for examining sands so that they could determine the possibility of using local sands for their work. One was interested in locating a sand similar to the French or Belgian sands.

Core Materials

As to core materials we find Michigan City sand and oil binders are most popular, especially among the nonferrous foundries. Ottawa sand and beach sands are also common. Linseed oil is not only the favorite oil binder but is used by more nonferrous foundries than any other one binder with kordek and dextrin ranking second and third respectively. Among steel, malleable and gray iron foundries, oil and water soluble binders are about equally popular. Rosin is also used by many of the malleable foundries. The use of clay, mazola and stucco as core binders was also reported.

About 20 per cent of the foundries reporting say they reclaim at least a part of their cores by crushing and adding water, sand, binder, etc. Several have found it practical to reclaim rosin and dextrin bound cores but not oil cores. They use the reclaimed sand in proportions ranging from 20 to 100 per cent of the batch. Additional binder is added in most cases as the burned sand tends to weaken the cores.

Very few reports of tests on cores were received, nearly all the foundries judging their sands and cores "by touch" or by "observation."

You will note that the information received is extremely meager and was not of much assistance in guiding the committee in preparing a program of investigation.

The work of the committee has been greatly retarded on account of two things; first, delay in receiving replies to questionnaires and second, on account of lack of standard methods for testing sands.

We are glad to say that some very interesting and constructive work has been done, by a few people, since our meet-

ing of a year ago. Some interesting data will be presented by Mr. Highriter, Mr. Harrington, Mr. Grubb and Mr. Lane.

Those who have accomplished results on the subject of conservation and reclamation have been forced to use their own methods of testing for investigation and control, consequently the results obtained by the various investigators cannot be compared, only in a general way. As soon as standard tests are obtained and adopted, we will then be able to speak the same language and hasten our work.

It is to be hoped that the foundrymen will begin to appreciate this important subject of conservation and reclamation and that they will give the committee the kind of co-operation that will lead to constructive and practical work.

Respectfully submitted,

F. L. WOLF, *Chairman.*

Discussion—Report of Sub-Committee on Conservation and Reclamation

E. M. Ayers.—There is one paragraph I would like to throw a little light on and that is on the question of molding sands, whether leaving them exposed to the weather helps them or not. I do not know whether people have tried both ways, leaving them out in the open or in storage under roof. For about 25 or 30 years, we have advised every one to have an open top on their sand bins, make concrete bins and leave the roof off and put the sand in there and use it as you need it, and the longer it was in there the better it would be. We knew this was a fact, but we did not know why, and we do not know now that we can tell you just why. We see in here that permeability tells the story. Very recently we took for a test the very tightest sand that was obtainable. Within one hour after it came out of the hill, having been bored back from where it had been away from the elements, and tested it for permeability; we laid it away out on a bench for 24 hours and next day its permeability was doubled; in the next 12 hours, it was increased 20 per cent, and after that it commenced to go down, which shows that the action of the elements on molding sands adds very much to its permeability. We do not know why that is, but this test proves it. We knew that molding sand shippers, shipping sand that had been stored in the winter and exposed to the elements, when that sand became exhausted and they started to ship fresh sand out of the pit, they all had the same complaint, that their customers were not getting the same sand. You who are iron molding sand people, can get the benefit of improving the quality of the molding sand by leaving off the tops of your storage bins.

R. J. Doty.—I would like to ask Mr. Ayers if, in testing that sand at different intervals, it was examined for moisture?

E. M. Ayers.—It was all done by standard, 6 to 8 per cent

of moisture, all worked under the same standard used by Mr. Wolfe. We obtained our information direct from Mr. Wolfe through our own chemist.

R. F. Harrington.—Do I understand Mr. Ayers to say that sand of 6 to 7 per cent moisture, tested for permeability one day, was then spread out on a table and tested for permeability the next day? How did you insure the same uniformity of moisture content on the second and third day as compared with the first?

E. M. Ayers.—We do not take the same sample; we take another sample that is part of that same sample but had not been used. We took the sample and dried it and added the moisture to it the next day, the same way, and made the same test. Everything done between 6 and 8 per cent, we find that all our tests, 4 per cent or 1 per cent, 2 per cent over or under, cuts the permeability in two, and the moisture content in foundry practice strikes us as important as anything else.

A. E. Hageboeck.—I would like to ask if there are any foundrymen here who use the open top sand bin and can tell us their experience?

Chairman R. A. Bull.—That relates to differences of opinion on that subject that were touched on in Mr. Wolfe's report and the replies to the questionnaire.

R. F. Harrington.—I might say that we have used the open top method of storing sand to the extent of about 25,000 tons a year with no bin at all. I think that the reason that some people gain in the strength and permeability of their sand after storing for six months is due to the fact that in one instance the moisture content is at a point where the permeability or the cohesiveness of the sand is not as great as it is at another. We learned from Dr. Ries' paper and the paper that I will present later, that there are certain moisture contents at which the sand has the greatest cohesiveness. Your sand ordinarily goes into your storage—in our particular case it seems to go in with a moisture content over and above the best moisture content for permeability and cohesiveness; therefore if the sand

during a period of 3 or 4 months, has a chance to lose a certain portion of the moisture content and arrive at the moisture content where you get your best cohesiveness, I think that is an explanation of the fact that in many instances the sand is improved by storing in the open.

Report of Sub-Committee on Testing Methods

To the Members of the American Foundrymen's Association

It has been the task of the Subcommittee on Testing Methods of the joint molding sand research committee to try to develop some tests worth while which, when applied, would give some practical and scientific information on the properties of molding sand. We have taken up the matter very aggressively in our work since the last convention in Rochester, holding many meetings, mostly in New York City and sometimes elsewhere, with the result that we have today the pleasure of presenting for your consideration, a group of tentative standard tests which our only regret is, are presented in a rather incomplete fashion. The rush work of the last two months on this subject has left us so that we did not have time to print these and distribute them ahead of the convention, but the information is pretty well in your hands by this time and with the help of some brief explanations regarding the details of the operations I think I can make clear the object of each of the tests.

You have been given for preliminary examination mimeographed copies of the tests considered by the committee as essential. It was not possible to similarly prepare descriptions of supplementary tests. Ultimately, of course, all of the methods tentatively adopted will be described completely in the records of the convention.

The *bonding or cohesiveness test* is intended to give results showing the comparative bonding qualities on molding sands and this, as you know, is one of the most important properties that we have to deal with. By means of this test we can easily detect either new sands or heap sands running low in bond and by daily tests, for instance, on the heap sands they can be kept up to standard requirements for certain classes of work. Incoming shipments of new sands can be checked for bonding

or cohesiveness and in this way a close watch kept on the uniformity of shipments.

The *permeability test* as now developed offers us the opportunity of testing the venting qualities of both new and used sands; it will prove a valuable test in the foundry, as its application will throw light on the venting problem, which is more or less of an unsolved question in foundry practice.

The *fineness test* is simpler in operation and application than either the permeability or bond test; it gives us direct information on the fineness and grain distribution of molding sands and also an accurate measure of the amount of clay substance present. The test will prove valuable as a check on incoming shipments of molding sands and also as a means of maintaining a uniform fineness in either the sand heaps or facings for particular classes of work. The specifications covering the sieves in this test lead to a uniform standard in this class of work and should result in bringing about comparative results in the hands of different investigators.

The *ultimate chemical analysis of molding sands* is not necessary for most sands, since the majority of shipments are from well know sources of supply where thorough investigation has proved that no objectionable constituents are present; on the other hand, many molding sands which might test out favorably in bonding properties, permeability and fineness, could be condemned from the chemical analysis. This method shows the amount of fluxing materials and the importance of these should not be overlooked when sands are being purchased from new sources not previously tried. Chemical analysis should be employed frequently on steel sands high in silica and intended for use as molding sands or core sands.

The *dye adsorption test* is recommended as a supplementary test; it deals with the colloidal matter present in the sand. The results obtained are a measure in a relative way of the amount of colloid matter contained and this gives us a means of comparing the quality of the bonding substances present. The quality of the bond in some sands is decidedly weak; in that case the dye adsorption test runs low. Other sands show a dye adsorption

figure running very high and this indicates a fat and plastic quality of the bonding substance. These sands are always much stronger and more desirable in the foundry.

The *method of sampling* tends toward standardization of this procedure and in case of dispute on shipments it will prove valuable, since it is a means of obtaining a uniform and representative sample of the shipment. The details are about the same as applied to shipments of coal and the method has proved reliable and practical.

In developing these tests the committee has been taxed to the utmost in time; we recognize the fact that we have not fully covered the ground yet and one of the most important investigations on molding sands is included in our work for next year. We must know the action of heat on a sand in order to fully comprehend what goes on in the mold when the metal fills it. Our aim will be to develop a test to cover the fusion point of the sand, which is one of the most important points in the testing of sands. This investigation may cover other important features which will disclose the refractory behavior of the sand and possibly the relative longevity.

The committee has, of course, not restricted its activities to attempts to originate new methods of testing. Obviously it would have been much easier for the committee if it could have ascertained that satisfactory methods of tests had already been developed, lacking only approval of a representative body to make them standardized and applicable to all sands, and to use by all investigators. It early became apparent that there were many valuable ideas that have been employed in testing sands, which lack certain details from the standpoint of standardization and intelligible results obtained in comparisons.

The sub-committee on tests has carefully studied all known testing methods, which might be of value in determining the important properties of molding sand. Direct methods which determine the significant properties are the most desirable from every standpoint. Among these, classified as essential, are tests for ascertaining the bonding strength or cohesiveness, the fineness, and the permeability of sand. In addition, certain indi-

rect tests are recommended for dye adsorption and for chemical analysis. These two tests are classed as supplementary.

Among other methods of tests, which the committee has on its own initiative investigated, is the vibratory test, originated many years ago but recently improved as to quickness and convenience of manipulation by Mr. Eugene Smith, of Chicago. We believe the vibratory test will in certain cases, including the routine use of known sands, be of some advantage in plant control. This method provides an approximation of the proportionate amounts of fine material and grain. In judging sands for bonding strength, permeability, or refractoriness, the vibratory test is regarded by the executive committee and the sub-committee on tests as being undependable. This conclusion has been reached after much experience in the use of this method by many members of the joint committee, some of whom employed this test in its essential features 20 years ago. Careful check tests recently conducted by some of the members of the joint committee absolutely verify the earlier independently formed conclusions of investigators who are now co-operating in this joint research.

Respectfully Submitted

H. B. Hanley, *Chairman.*

Bonding or Cohesiveness Test

Tempering of Sand

1. The sample to be tested should be an average one, representative of the heap, floor, car[1], bank[1], or other source from which it is taken.

2. In testing sand for cohesiveness it is absolutely necessary that the sand be properly sampled and uniformly tempered. For plant check or control tests upon facing or heap sands in daily use, one may test the sand as tempered for molding.

3. Since it is the object to determine the maximum cohesiveness under suitable foundry working conditions, in the examination of new sands experiment should invariably be made with several water contents in order to ascertain that amount (optimum water content) which develops the maximum degree of cohesiveness. It is advisable in most cases to try percentages of water beginning with 4 per cent and increasing by stages of 2 per cent. up to and including at least 8 per cent. Sometimes it will be found difficult to make a test with a water content of an exact predetermined percentage. The permissible extent of deviation from the predetermined amount should in no case be more than one-half per cent, and can be intelligently determined by the careful experimenter who observes critically the tendency of a sand to show widely differing cohesiveness values as the water content is appreciably changed. A deviation not exceeding .2 per cent (5.8 per cent or 6.2 per cent in the case of an attempt to get 6 per cent) can be considered as entirely satisfactory for the determination of the cohesiveness at the nearest fixed percentage. The exact percentage of moisture, even if within .2 per cent should be reported. Supplementary tests with lower percentages of water than 4 per cent and higher percentages than 8 per cent should be made if and when the facts ascertained justify such tests. For example, when a permeability value considered proper to report is obtained on a sand with a moisture content below 4 per cent or above 8 per cent and a cohesiveness value on the sand is desired, the test for co-

[1]Directions given under "Sampling of Molding Sands as Shipped or Delivered" cover this point in detail.

hesiveness should be conducted with the sand tempered with the same amount of water as in the case of the permeability test. In such cases, a sufficiently large sample of sand should be tempered, to permit making both of these tests.

4. In the examination of new sands, proceed as follows: Dry 1000 grams of sand, selected according to the directions for sampling molding sand, for one hour at a tempearture not below 105 degrees Cent., nor above 110 degrees Cent. Care should be exercised to spread the sand over a large area in a thin layer in order to expel all the moisture in a given time. This will make it possible to add the proper amount of water and give the sand the desired moisture content.

5. After the sand has cooled, measure out the desired quantity of water, adding sufficient extra water (usually from one-fourth to one per cent) to allow for evaporation during mixing. Thus if it is desired to add 4 per cent water and one-half per cent extra water is needed, one would add 47 cubic centimeters (since one cubic centimeter of water weighs 1 gram) to 1000 grams, and secure a total weight of 1047 grams.[2]

6. For the tempering operation, spread the sand on a smooth flat dry surface in a layer about 1 inch thick, sprinkle a small quantity of the required water evenly over the sand, and work the latter gradually into a heap by rubbing it vigorously through the hands. Again spread it into a thin layer and repeat the above operations, adding more water. Continue to do this until all of the water has been thoroughly distributed through the sand. There should be no dry lumps or other evidence of uneven tempering.

7. The sand should now be allowed to stand in order that the maximum temper may be developed. To secure this temper, place the sand in a humidor or air-tight receptacle and allow it to stand for 24 hours. After this, the sample is ready to be tested, as below.

8. Take the entire sample of sand from the humidor. Pass this entire sample twice through a coarse riddle and return the

[2]Moisture content for all molding sand determinations and tests is to be expressed as the percentage of moisture in the *damp* sample of sand. It is not proper to calculate the amount of moisture, proportionate to the weight only of the dry sand.

sand as quickly as possible to the humidor or receptacle. From this take sample to be tested for cohesiveness; also sample to be tested for moisture content, and for permeability if desired.

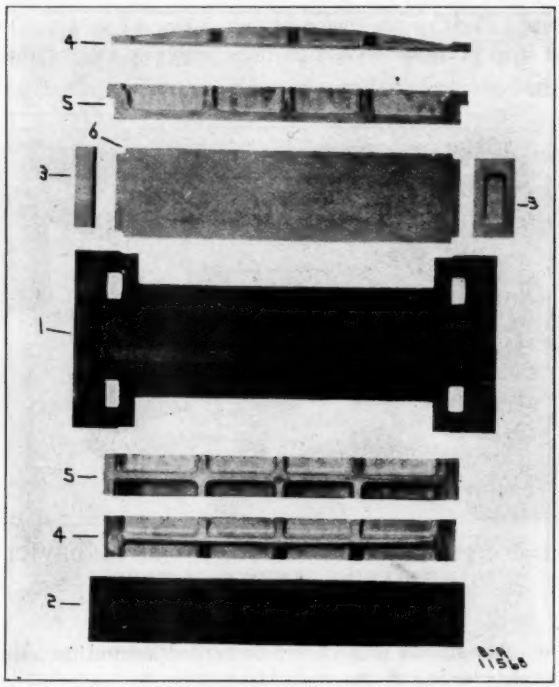

FIG. 1—MOLD BOX PARTS FOR BOND TEST

Ascertaining Moisture Content

9. The moisture content is to be determined as follows: Dry 100 grams of tempered sand for one hour between 105 degrees and 110 degrees Cent. When dry reweigh. The loss of weight in grams is the moisture content expressed as percentage.

Method of Procedure in Testing for Cohesiveness

10. While the sand is drying remove all loose pieces from the box as shown in Fig. 1. Replace metal plate (No. 6, Fig. 1)

in frame (No. 1, Fig. 1), locating the plate between the small projections on the bottom of the frame; and upon this plate[3] place a piece of thin waxed or oiled paper which is of the same width as the end of the plate, but long enough to be inserted in the slotted shaft of the motor-pulling device (Fig. 2). One end of the strip of paper should be even with one end of the plate,

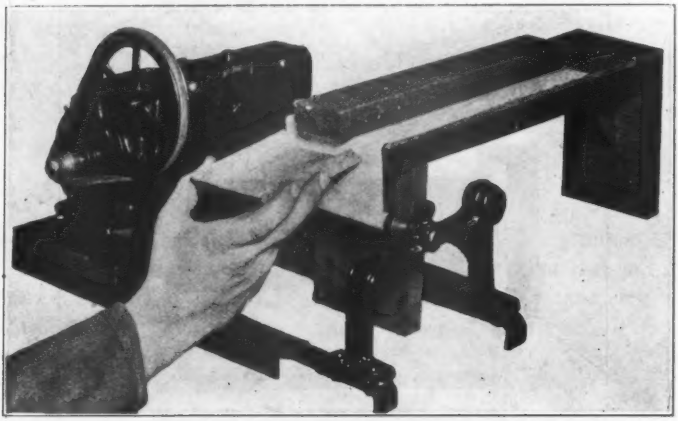

FIG. 2—CONSTANT SPEED MOTOR PULLING DEVICE FOR BREAKING BOND TEST BARS

and the other should project and be turned around the other end of the plate, so as to lie smoothly against its under side. Replace sections 5 (Fig. 1), moving them as far toward the outer edge of the frame as is possible. Then replace sections 3 (Fig. 1). Place the open box directly beneath the riddle which is shown together with the box and strikes in Fig. 3.

11. Take an amount of tempered sand equal in weight to 1000 grams of dry sand plus the proper percentage of water in grams. Place the weighed sand and some tumbling barrel stars in the riddle, and shake the riddle until the sand has passed

[3]The metal plate can be made of aluminum, brass, or of some other non-corrosive metal. The light weight of aluminum makes it preferable for handling.

through it.[4] Remove the box from beneath the riddle, and brush all particles on top of sides of box, into same.

12. Level off the sand in the box by using the strikes shown in Fig. 4. In striking off, it is important to start with that strike which grazes the highest level of the sand, working from the center alternately toward the ends of the box, and swinging the strikes around as the ends are approached, so that

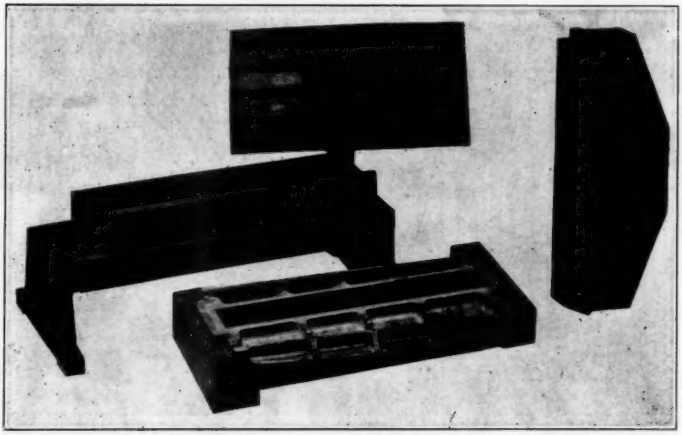

FIG. 3—ASSEMBLED MOLD BOX, SCREEN AND RAMMER BLOCK FOR BOND TEST

no sand will be packed between the strike and the end of the box. Continue the use of strikes consecutively deeper by 1/16 inch until a uniform level of sand is obtained throughout the box.

13. Starting with section 5 on one side of the box, push it toward the center as far as possible, and hold in position by inserting section 4 (Fig. 5). Repeat this operation on opposite side.

14. Place the trussed rammer (Fig. 6) in a level position on the sand in the box. Place the box with the trussed rammer

[4]In the case of some coarse sands like Millville gravel there is a tendency for the finer particles to go through the screen of the riddle first, the coarser particles and pebbles passing through later. This tends to give a layered structure to the bar, which is undesirable. Where the sand shows such a tendency the use of a coarser screen in the riddle for feeding the material into the box is permissable.

in an impact machine similar to that shown in Fig. 7, so that the weight will fall on the center of the truss. Drop a twenty-pound weight, three times from a height of sixteen inches.

15. Remove box with trussed rammer from impact machine. Then remove trussed rammer and sections 4, 5 and 3 in the order named. In removing section 3 be especially careful to push it away from the bar as it is being lifted.

FIG. 4—SHOWING METHOD OF LEVELING SAND IN MOLD BOX USING STRIKES OF GRADUATED DEPTH

16. Remove metal plate supporting the bar lying on the paper. With a scale divided into hundredths of an inch, measure both sides of the bar at three points to determine the average thickness, considering the inch to be the unit of thickness. The thickness should be uniform, but experiments have shown that variations in thickness do not appreciably affect the results when the deviations in the thickness of the bar do not vary from the prescribed one inch dimension, over or under, at any point, by more than .02 inch. Set the plate carrying bar and paper on the table of breaking apparatus (Fig. 2), with one end of the plate projecting about one-half inch beyond the end of table. The free end of the paper should extend from the projecting

end of the plate, and should pass through the slot in the shaft of the motor-pulling device (Fig. 2).

17. Start the motor-pulling device[5], which draws the bar forward at the rate of six inches per minute. When the weight of the overhanging section causes a portion of the bar to break off, stop the motor. Catch the portion breaking off in some convenient receptacle (as illustrated in Fig. 2) which has been previously weighed. This receptacle may be a piece of thin metal which has been bent into a shape similar to a bowl or scoop

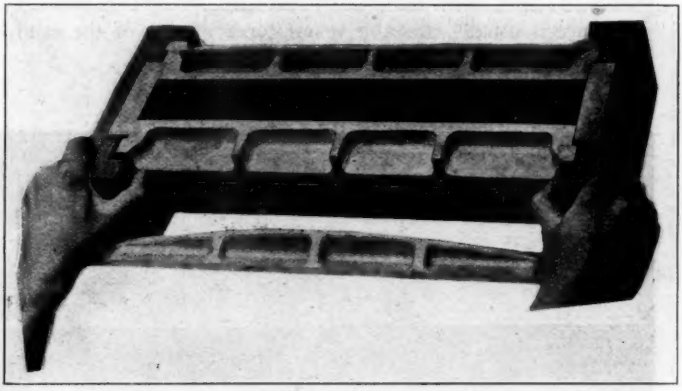

FIG. 5—SHOWING METHOD OF ASSEMBLING MOLD BOX AFTER SAND HAS BEEN RIDDLED IN BOX

so as to safeguard the catching of every particle of sand as it falls. Weigh the receptacle and every particle of the broken portion of the bar together, and deduct the weight of the receptacle. Repeat the operation until as many breaks are obtained as the bar will yield. To prevent the last part of the bar from tilting a broad flat weight of proper size may be placed on the end of the bar to hold it down.

[5]Instead of the motor-pulling device illustrated, any suitable form of apparatus may be used, which employes power geared to a shaft in such ratio that the said shaft to which the paper is attached will be revolved at a constant speed to draw the bar at six inches per minute. A steady forward movement of the bar for each break is imperative. For intelligent comparison of results a uniform pulling speed, to be employed by all operators, is necessary. A speed of six inches is adopted because it has been found satisfactory with weak and strong sands.

Disposition of Results from Tests

18. If the bar breaks into portions of fairly uniform weights, all breaks may be retained. If the first break differs by more than 10 per cent from the average weight of the others discard it. Appreciable variations between the weight of the first break and those of the other breaks may be due to the influence on certain sands of close contact with the end piece of the box (No. 3, Fig. 1). Should the weight of any break other than the first differ from the average weight of the others by more than 10 per cent, discard the entire bar. This difference is usually traceable to improper mixing of the sand or careless use of the strikes.

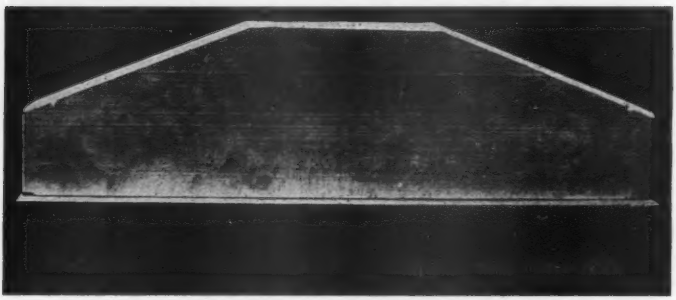

FIG. 6—RAMMER BLOCK FOR BOND TEST

19. Add the weights of all broken sections (except any which may have been discarded) and divide by the number of these. This gives the average breaking weight for a bar of the thickness used. Repeat this operation, until at least six breaks have been obtained from not less than two bars, and average the results of the average breaks from each bar. If properly carried out, the test of the number of bars as specified in paragraphs 4 should yield averages which do not vary more than 5 per cent from each other. Failure to meet this requirements indicates faulty manipulation.

20. The bonding strength is to be expressed in percentage. As few sands are likely to approach 500 gram breaks, let this weight equal 100 per cent. The bonding strength expressed in percentage is obtained as follows:

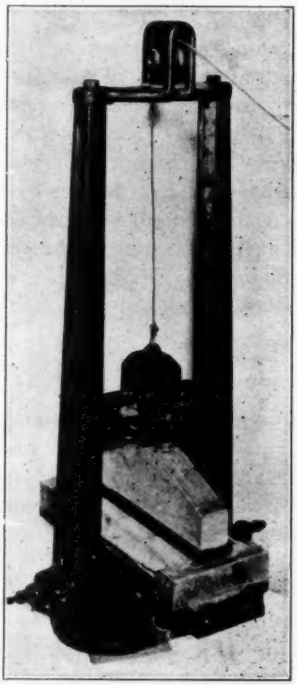

FIG. 7—RAMMING APPARATUS FOR COMPRESSING SAND IN MOLD BOX FOR BOND TEST

Example A

Bonding Strength = 213.6 × 100 ÷ 500 = 213.6 ÷ 5 = 42.7 *per cent.*

Example B

Bonding Strength = 252.9 × 100 ÷ 500 = 252.9 ÷ 5 = 50.6 *per cent.*

21. From the above examples it is seen that the average weight of the breaks, divided by 5, gives the bonding strength or cohesiveness expressed in percentage.

22. Having completed the test on samples with varying moisture contents, report the bonding strength or cohesiveness of each, with its corresponding moisture content.

Permeability Test

Adopted as Tentative Standard[1] Cleveland Convention 1923

Introduction

1. The term "permeability" as used in this test, is that physical property of sand which permits the passage of gases. It is upon this property of permeability that the venting qualities of sand molds and cores depend. A sand of high permeability has good venting quality because of its "openness." The natural characteristics of the sand and its binders, the density with which these are packed, and the percentage of moisture used for tempering, are important factors in regulating the degree of permeability. The object of the permeability test is to determine the rate of the flow of air per unit pressure through a standard specimen of sand.

Permeability Apparatus

2. The apparatus consists of the following arrangement of parts whose functions are indicated in the accompanying description. A 4-liter water reservoir bottle (A) is provided, with three glass tube connections. An overflow (1), through a ¾ inch (1.9 cm) tube, maintains the constant height of water level. A supply water tube (2), diameter ½ inch (1.27 cm), extends below the water level, and supplies water to reservoir when the apparatus is in operation. A water outlet tube (3) diameter 6 mm, having a 6 mm stop-cock (9), with a 4 mm hole, delivers water from the reservoir bottle (A) to the air displacement bottle (B). The height of constant water level in reservoir bottle (A) is 18 inches (45.72 cm) above the discharge side of the 4 mm hole of stop-cock (9), and the end of the tube is 4½ inches below the stop-cock.

3. An 8-liter air displacement bottle (B) is provided, which has connected to it through a rubber stopper, a water outlet tube (3) as described above, and an air outlet tube (4), diameter ½ inch (1.27 cm) which leads to a manometer (C), a water level gauge (D), and sand container (E).

1. See revision of test method for permeability, page 708.

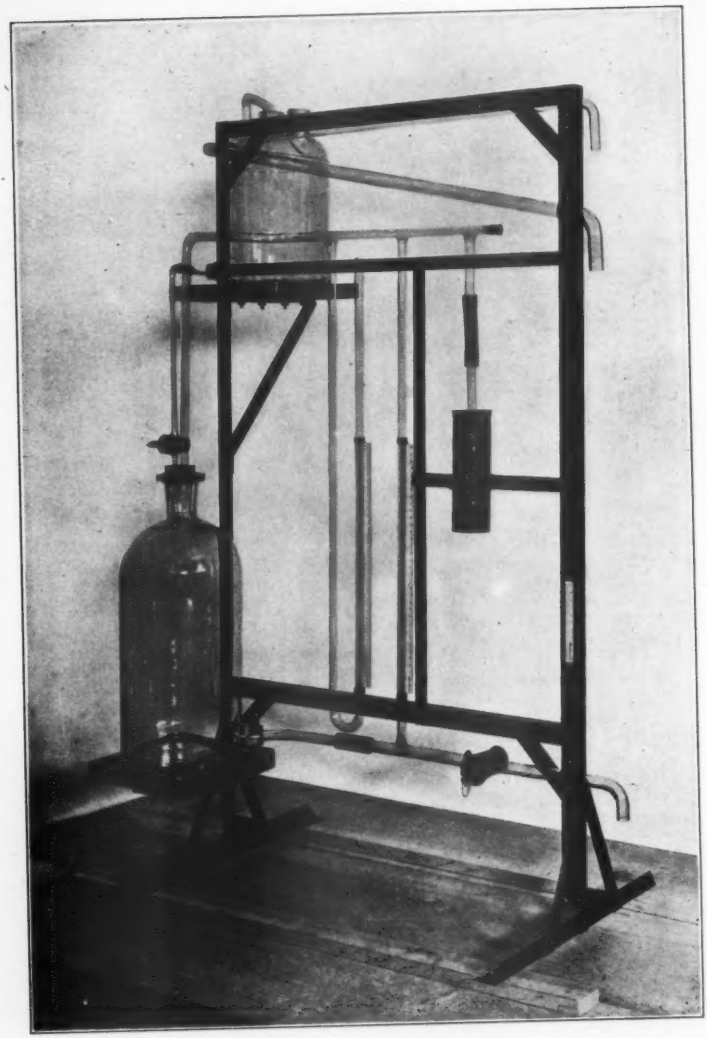

FIG. 1.

4. The manometer (C) has placed behind it a paper scale line drawn across this scale at approximately the center, is zero. Centimeters divided into tenths are laid off in both directions from this center line. One cubic centimeter of water weighs one gram. Therefore each reading of one centimeter on this scale indicates a pressure of one gram per square centimeter. The manometer (C) contains sufficient water to bring the level in both legs to the zero line. The end of air outlet tube (4) is closed and opened by means of a rubber stopper (5), or stop-cock, if it is desired to substitute this for a stopper.

5. A water level gauge (D) is provided with a paper scale placed behind it, graduated to show cubic centimeters of air displaced in bottle (B), which should be calibrated in units of 1000 cc (1 liter). The air displaced in bottle (B) is read in liters by noting the rise of the water column in gauge (D).

6. The sand container (E) is a brass cylinder 6 inches (15.24 cm) high, and 2 inches (5.08 cm) inside diameter.

7. The rammer[2] consists of a steel rod having a diameter of ¾ inch (1.90 cm), supported by two steel guides. A steel disc 1 inch (2.54 cm) thick, and 1 31/32 inches (5 cm) in diameter, is attached to the lower end of the rod. This disc has a sliding fit in the sand container (E). A cast iron rammer-head weighing 14 pounds (6350.36 grams), slides on the rod, its movement being regulated by two stops. The distance between these stops is sufficient to permit a 2-inch (5.08 cm) movement of the rammer-head. The total weight of the assembled rammer, including disc, rod, stops, and head is exactly 17.5 pounds (7938 grams). A pedestal is provided on which the sand container (E) rests while the sand is being placed in this container; and while the ramming operation is shown in the illustration.

Principle of Operation

8. The water flows from the reservoir bottle (A) into the displacement bottle (B), thereby forcing the air from bottle

2. The rammer is shown in Fig. 4, Page 714.

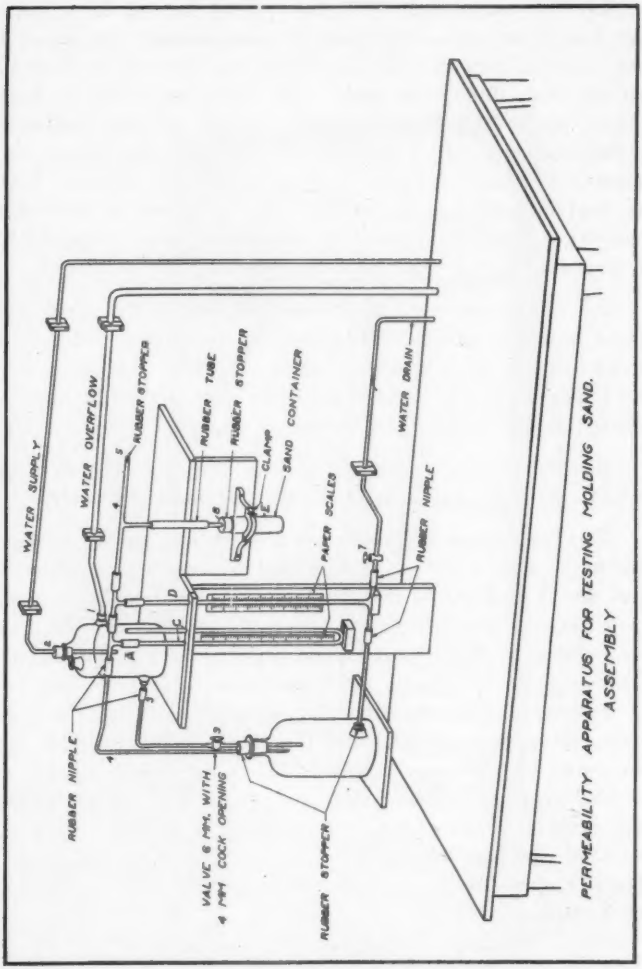

FIG. 2—ASSEMBLY VIEW OF PERMEABILITY APPARATUS FOR TESTING SAND

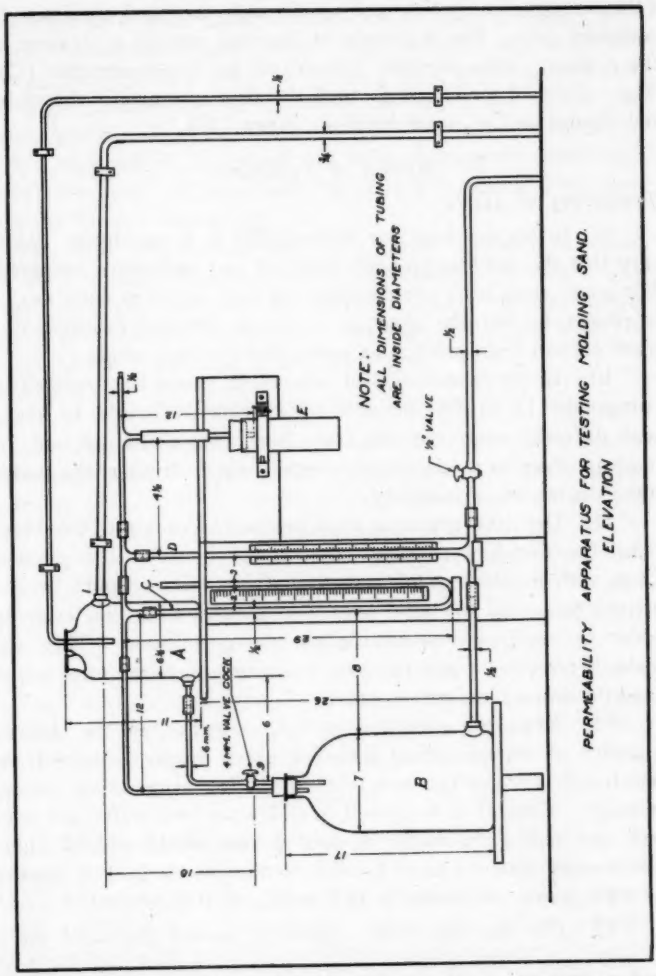

FIG. 3—ELEVATION OF APPARATUS FOR TESTING MOLDING SAND

(B) through the system and on through the sand specimen in container (E). The resistance of the sand sets up a pressure in the system. This pressure is indicated by the manometer (C). The volume of air forced through the sand specimen is shown by the change in the water level on gauge (D),

Method of Procedure

Tempering of Sands:

9. In testing sand for permeability it is absolutely necessary that the sand be properly sampled and uniformly tempered. For plant check tests upon facing and heap sands in daily use, it is proper to test the sand as tempered for the molders. For plant control tests proceed as prescribed for new sands.

10. In the examination of new sands, proceed as outlined in paragraphs 11 to 14, inclusive. Experiments should be made with different water contents from 2 per cent to 10 per cent, or more in order to ascertain that content which develops the maximum degree of permeability.

11. Dry 1000 grams of sand, selected according to the directions for sampling molding sand, for 1 hour at 105 degrees Cent. with a tolerance of 5 degrees Cent. Care should be exercised to spread the sand over a large area in a thin layer in order to expel all moisture within the given time. This will make it possible to add the proper amount of water to give the sand the desired moisture content.

12. After the sand has cooled, measure out the desired quantity of water, adding sufficient extra water (usually from one-fourth to one per cent) to allow for evaporation during mixing[3]. Thus, if it is desired to add 4 per cent water and one-half per cent extra water is needed, one would add 47 cubic centimeters water (since 1 cubic centimeter weighs 1 gram) to 1000 grams, and secure a total weight of 1047 grams[4].

13. For the tempering operation, spread the sand on a

[3]The drying of the sand during the mixing period can be avoided by working the sand in a large tent-humidor. The humidor may consist of a water pan 30 inches square and 2 inches deep supported on a wooden frame, which is surrounded by previously saturated muslin. The upper edge of this muslin is folded over into the pan of water, and the resulting capillary attraction provides the moisture and the effect of a humidor. Do not leave sand in the tent-humidor after mixing, as some sands may absorb additional moisture from the tent atmosphere.

[4]Moisture content for all molding sand determinations and tests is to be expressed as the percentage of moisture in the *damp* sample of sand. It is not proper to calculate the amount of moisture, proprotionate to the weight only of the dry sand.

glass plate in a layer about 1-inch thick, sprinkle a small quantity of the required water evenly over the sand, and work the latter gradually into heap by rubbing it vigorously through the hands. Again spread it into a thin layer and repeat the above operations, adding more of the water. Continue to do this until all of the water has been thoroughly distributed through the sand. There should be no dry lumps or other evidence of uneven tempering.

14. The sand should now be allowed to stand in order that the maximum temper may be developed. To secure this temper, place the sand in a humidor or air-tight receptacle, and allow it to stand for 24 hours. After this, the actual work of testing shall be carried out as indicated below.

Ascertaining Moisture Content

15. Pass the entire sample of sand twice through a coarse riddle, and return the sand as quickly as possible to the humidor or receptacle. Next determine the moisture content[5] as follows: dry 100 grams of tempered sand for 1 hour at 105 degrees Cent. with a tolerance of 5 degrees Cent. When dry, reweigh. The loss of weight in grams is the moisture content expressed as percentage. When determining the permeability of sand having a definite moisture content, a deviation not exceeding 0.2 per cent from the desired water content is permissible. For example, sand intended to have a moisture content of 6 per cent must have an actual moisture content of not less than 5.8 per cent or more than 6.2 per cent.

Ramming

16. Take a sufficient quantity (from 150 to 200 grams) of tempered sand to make a column 2 inches (5.08 cm) high, with a tolerance of 4 per cent. The sand should be carefully placed in the container (E), and gently leveled off. Place pedestal and container with sand in position beneath rammer. Gently lower rammer-rod with head into container until they are supported by the sand. Raise rammer-head to the upper stop, and let fall. Repeat twice, making a total of three rams. Note whether the upper end of the rod is within the tolerance marks.

[5]See footnote 4, page 702.

It not, discard the sample and put in another lot of tempered sand of sufficient quantity to yield a column of the required height. This is usually accomplished on the second trial. Lift until entire rammer-rod is removed from container, and take container off pedestal. Place container in permeability apparatus, seeing that the rubber stopper (8) fits tightly in upper end of container (E). Then close tube (4) with a rubber stopper (5), or stop-cock.

17. The sand specimen is now to be tested. Turn on water into bottle (A), and regulate the flow into this bottle when valve (9) is open, so that the level of the water in bottle (A) will be just sufficient to permit constant discharge through overflow (1). Open valve (9) *wide*, permitting water to flow into air displacement bottle (B). The rise of the water in gauge (D) from the mark indicating 2 liters, to that indicating 4 liters, shows a displacement of 2000 cubic centimeters of air in the bottle (B). With a stop-watch prepare to ascertain the time. Determine this at the instant the water level or maniscus passes the 2-liter mark, and again at the instant the water passes the 4-liter mark, noting the number and fractional parts of minutes required for the movement of the water between these two marks When the water passes the 4-liter mark, stop the water flow into bottle (5) by closing valve (9). While the interval of time is being determined for the movement of the water between the said marks, take two separate readings of the pressure in the manometer (C), and record the average. As the observed reading on the manometer scale is only that pressure in one leg of the manometer, multiply this average observed reading by 2 to get the actual pressure of the air on the sand. This is the pressure to be recorded.

18. To force the air through the same specimen a second time, again let the water into bottle (B) by opening valve (9). As the water level passes the 5-liter mark on the scale of the water level gauge (D), start the timing period, stopping at the 7-liter mark, and repeat the other operations outlined in the preceding paragraph. To obtain more than two determinations on the specimen, open tube at (5) and drain bottle (B) and water level gauge (D) by opening valve (7). When water level has

dropped to approximately one inch below the 2-liter mark on water level gauge (D), close valves (7) and (5). The apparatus is now ready for another test. Make sufficient determinations on the same specimen to obtain at least three pressure readings that are uniform, in which the time does not vary by more than 1 per cent.

Calculation of Permeability

19. The degree of permeability as determined by this test is found by employing a formula. By its use, permeability is ascertained as the volume of air per minute, per gram per square centimeter pressure, per unit volume in specimen.

Permeability equals the cubic centimeters of air forced through the sand specimen, multiplied by the height of the sand specimen in centimeters; divided by the pressure in grams, multiplied by the area of the sand specimen in square centimeters; divided by the minutes of time. Thus:

$$\text{Permeability} = \frac{\text{cm}^3 \text{ of air} \times \text{cm height of specimen}}{\text{grams pressure} \times \text{cm}^2 \text{ area of specimen}} \div \text{minutes}$$

The method of conducting the permeability test herein described calls for 2000 cm^3 of air to be forced through the specimen; 5.08 cm (2 inches) to be the height of the specimen; and 20.268 cm^2 (3.1416 square inches) to be the area of the specimen. These fixed quantities are therefore substituted as constants in an equation as follows:

$$\text{Permeability} = \frac{2000 \times 5.08}{\text{grams pressure} \times 20.268} \div \text{minutes}$$

Reduced to its simplest terms this equation reads:

$$\text{Permeability} = \frac{501.2}{\text{grams pressure} \times \text{minutes}}$$

Revision of Permeability Test

On May 1, 1923, at the Cleveland convention of the American Foundrymen's Association, the Joint Committee on Molding Sand Research announced its tentative adoption for one year, of several methods of test, including one for determining permeability. It was explained at the time that efforts would be made to simplify the tests so that, if possible, they might be modified with advantage in experimental and routine investigations.

The sub-committee on tests of the joint committee recognized the fact that the apparatus required for the permeability test as originally promulgated was somewhat expensive and susceptible to breakage, causing complications in renewals. There was no indication that the original method was not entirely satisfactory as to correctness. The desirability of having a method whose correctness was not questioned prompted the joint committee to tentatively adopt for trial the method which was admittedly liable to certain objections. It was felt that this procedure would be better than delay caused by approving a different method after ascertaining by many experiments the exactness of the same as checked by the original method.

The sub-committee on tests has during the last year given a great deal of study to the problem of a simplified permeability test. As a result, a modification of the original method embodying the same principles, but requiring apparatus much less costly and much less liable to breakage, has been developed. The revised method has been tentatively adopted by the executive committee of the joint committee, effective May 1, 1924. By such tentative adoption the original apparatus and method of using same, as announced at the Cleveland convention, are automatically eliminated from the testing procedures now advocated by the joint committee. The apparatus required for the revised method includes the same ramming device as was required for the original method. The other equipment for the revised procedure is entirely different from that used for the original test.

In discarding the original apparatus and in tentatively adopting for trial one of simplified form, the joint committee wishes to make plain that permeability values as they may be determined by any who have purchased apparatus for the original method, and who may wish to continue the use of that apparatus, will be found perfectly reliable. There may be other pieces of apparatus and methods of test in use by experimenters which are equally satisfactory. Tentative adoption of the method for determining permeability described in the following section indicates unqualified official approval of the best method for determining permeability from the standpoints of accuracy and simplicity, of which the committee has knowledge, after prolonged and thorough consideration of the subject, investigation of various forms of apparatus, and development by the committee of many kinds of testing equipment for experimental work.

Permeability Test

(*Revised May* 1, 1924)

Introduction

1. The term "permeability" as used in this test, is that physical property of sand which permits the passage of gases. It is upon this property of permeability that the venting qualities of sand molds and cores depend. A sand of high permeability has good venting quality because of its "openness." The natural characteristics of the sand and its binders, the density with which these are packed, and the percentage of moisture used for tempering, are important factors in regulating the degree of permeability. The object of the permeability test is to determine that physical property of the sand called permeability. This is ascertained by measuring the rate of flow of air through a standard specimen of sand under a given pressure. It may have for its purpose the making of standardized tests or the routine control of sand mixtures in foundry operations.

Permeability Apparatus

2. The parts[1] of the permeability apparatus are as follows: Tank A (Figs. 1 and 2) is made of copper, tin lined, and is provided with a vertical air outlet tube coming up through the bottom of the same. When in use this tank is partly filled with water as described in paragraph 21. A stop-cock is provided on the side of tank A at the bottom, to drain off the water when the apparatus is not in use, or when adjusting the water-level. Bell B has a vertical tube, (C-1 Fig. 2) which slides inside the air outlet tube (C-2 Fig 2) in tank A. Near the top of this tube are several vents to permit the air to be forced out of bell B. A three-way valve D (shown assembled in Fig. 1) is attached to the lower end of the outlet tube from tank A. The opening in the valve should not be too

[1]Dimensions of the different parts are given on the parallel perspective drawing (Fig. 2).

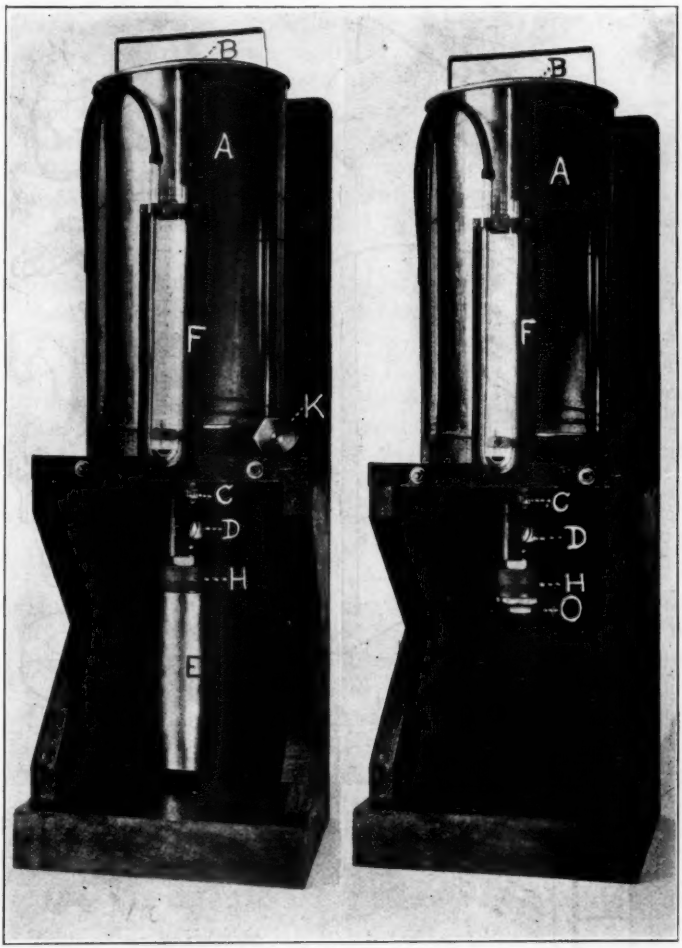

FIG. 1A FIG. 1B

PERMEABILITY TESTING APPARATUS. THE APPARATUS ON THE LEFT HAS A SAND CONTAINER (E) IN PLACE READY FOR TESTING.

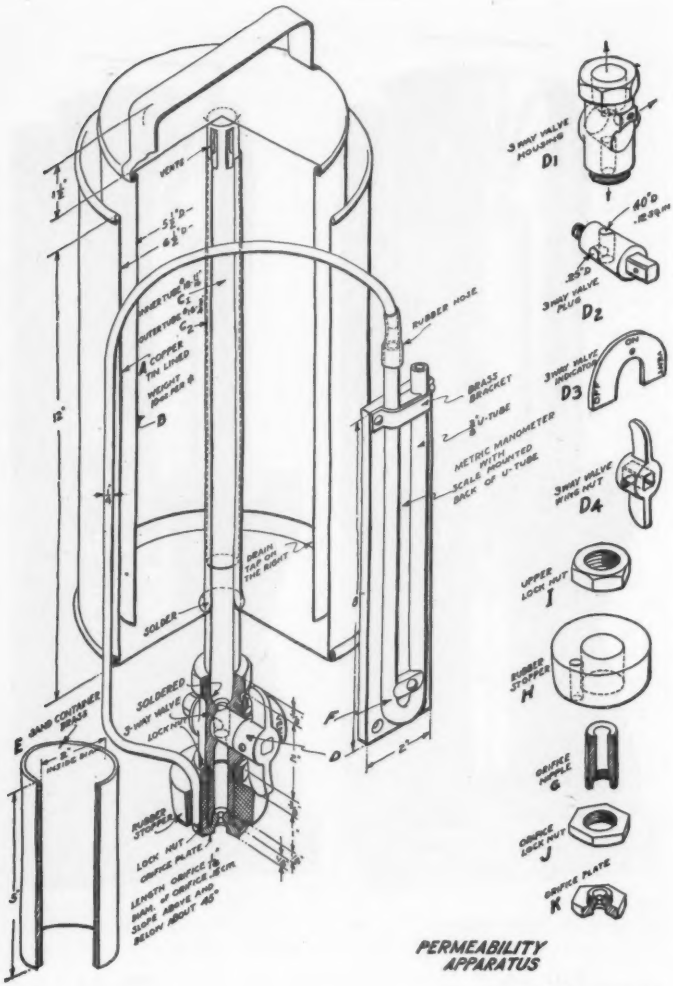

FIG. 2.—PARALLEL PERSPECTIVE DRAWING OF PERMEABILITY TESTING APPARATUS

small, preferably not less than .12 square inches (3 square millimeters) so as to permit the air to pass through freely. The parts of this valve are shown as D1 to D4, inclusive (Fig. 2). A valve-indicator, D3 is provided, marked "On," "Off," and "Vent," to show when the valve is in position to let air from bell B through sand in sand container E; to shut off flow of air from bell; or to permit air to enter by-pass while raising the bell. A nipple G, over which fits a rubber stopper H, which is held in place by two locknuts I and J, is attached to the lower side of the valve. An orifice-plate K for use in rapid work, is screwed into the lower end of the nipple G. One of the orifice-plates can be seen on the shelf at base of tank (Fig. 1A). The rubber stopper H fits into a sand container E. In front of the tank A, there is a manometer F, having a scale divided into centimeters and millimeters. This connects with a brass tube that passes down through the rubber stopper H. All parts are of brass, except those described as being made of other materials, and except the stand or base.

3. As the bell B sinks into the water in tank A, it forces air into the outlet pipe C-1 (Fig. 1) through the valve D (Fig. 1), and through the sample of sand packed in the container E (Fig. 1 A). The pressure of this air is read on the manometer F. Since the pressure recorded on the manometer depends on the weight of the bell B, and on its cross-sectional area, the weight should be made such as to give a pressure of about, but not less than 1.1 ounce per square inch (5 grams per square centimeter)[2]. There should also be a weight provided, which can be placed on top of bell B, sufficient to increase the manometer pressure reading to 10 centimeters. This latter pressure is more convenient for testing very fine sands and for rapid work. An easily graduated weight is a bag of shot.

4. The bell B has several lines marked on it, the lowest being "X", the second "O", the next "1000" and the fourth "2000." These indicate that the capacity of the bell between the "O" and "1000" marks is 1000 cubic centimeters (61 cu. in.),

[2]If less than 5 centimeters pressure is recorded the bell sinks too slowly when a very fine sand is being tested. The amount of pressure can be determined by attaching the empty sand container to the apparatus, plugging its lower end with a cork,and opening the valve.

and between "O" and "2000" it is 2000 cubic centimeters (122 cu. in.).

5. The object of having the mark "X", which is about ¾ inch (19 millimeters) below the zero mark, is to insure raising the bell to the proper height, so that when it is necessary in a standard test to read the time required for the bell to sink from zero to 1000 or 2000, the zero mark will be clearly visible.

6. To raise the bell, turn the indicator on valve plug to "Vent" (Fig. 2). This allows air to enter through the by-pass instead of having to be drawn through the sand. Then turn indicator to "Off", and the bell will remain in its raised position. When ready to start the test, turn indicator to "On", and the bell will sink as air is forced through the valve.

7. The sand container E (Fig. 1A) is a brass cylinder 5 inches (12.70 centimeters) high and 2 inches (5.08 centimeters) inside diameter.

8. The sand rammer is shown in Fig. 3, with detailed drawings in Fig. 4. It consists of a steel rod, supported by two guides. A steel disc is attached to the lower end of the rod, and has a sliding fit in the sand container E (Fig. 1A). A cast iron rammer head, weighing 14 pounds (6350.36 grams), slides on the rod, its movement being regulated by two stops. The distance between these stops is sufficient to permit a 2 inch (5.08 centimeters) movement of the rammer-head. A pedestal is provided on which the sand container E rests while sand is being placed in it; and while the ramming operation is being performed. This pedestal is shown in Fig. 4.

9. On top of the upper steel guide is attached a scale with 3 lines marked on it. If the upper end of the rammer rod is between the upper and lower of these lines after the third ram, it indicates that the sand sample is within the allowable limits of thickness.

10. If dry sand is to be tested, a special cap having a 20-mesh brass screen bottom should be used, to slip over the end of the sand container. For ramming dry sand the pedestal can be placed upside down under the container. This supports

the screen during ramming, and keeps the sand sample at proper height to use the tolerance marks as a guide.

Preparation of Sample

The sample to be tested should be an average one, representative of the heap, floor, car[2], bank or other source from which it is taken.

Tempering of Sand

12. In testing sand for permeability it is absolutely necessary that the sand be properly sampled and uniformly tempered.

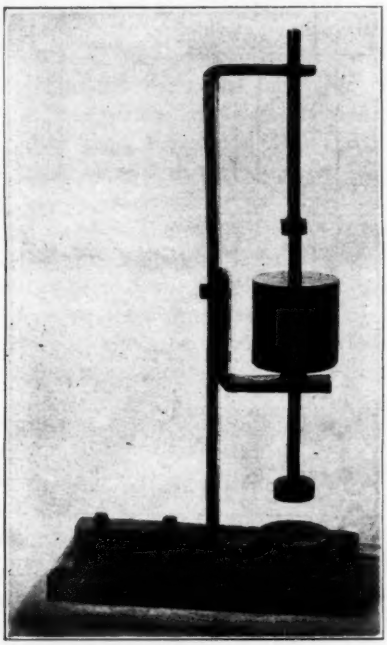

FIG. 3

For plant check or control tests upon facing or heap sands in daily use, one may test the sand as tempered for molding.

[2]Directions given under "Sampling of Molding Sands as Shipped or Delivered" cover this point in detail.

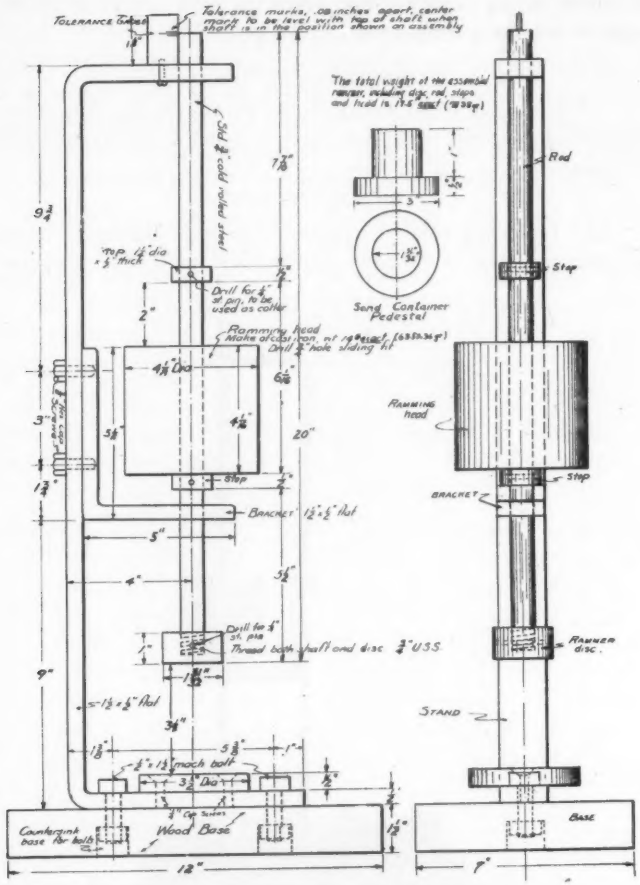
Tolerance Tube
Tolerance marks, 08 inches apart, center marks to be level with top of shaft when shaft is in the position shown on assembly
The total weight of the assembled rammer, including disc, rod, stops and head is 11.5 lbs. (5.22 kg.)
Rod
Stop
Sand Container Pedestal
Ramming head
Bracket
Rammer disc
Stand
Base
Wood Base
Countersink base for bolts

FIG. 4—RAMMING DEVICE FOR PERMEABILITY TEST

13. Since it is the object to determine the maximum permeability under suitable foundry working conditions, in the examination of new sands experiments should invariably be made with several water contents in order to ascertain that amount (optimum water content) which develops the maximum degree

of permeability. It is advisable in most cases to try percentages of water beginning with 4 per cent and increasing by stages of 2 per cent, up to and including at least 8 per cent. Sometimes it will be found difficult to make a test with a water content of an exact predetermined percentage. The permissible extent of deviation from the predetermined amount should in no case be more than one-half per cent, and can be intelligently determined by the careful experimenter who observes critically the tendency of a sand to show widely differing permeability values as the water content is appreciably changed. A deviation not exceeding .2 per cent (5.8 per cent or 6.2 per cent in the case of an attempt to get 6 per cent) can be considered as entirely satisfactory for the determination of the permeability at the nearest fixed percentage. The exact percentage of moisture, even if within .2 per cent, should be reported. Supplementary tests with lower percentages of water than 4 per cent and higher percentages than 8 per cent should be made if and when the facts ascertained justify such tests. For example, when a cohesiveness value considered proper to report is obtained on a sand with a moisture content below 4 per cent or above 8 per cent and a permeability value on the sand is desired, the test for permeability should be conducted with the sand tempered with the same amount of water as in the case of the cohesiveness test. In such cases, a sufficiently large sample of sand should be tempered, to permit making both of these tests.

14. In the examination of new sands, proceed as follows: Dry 1000 grams of sand, selected according to the directions for sampling molding sand, for one hour at a temperature not below 105 degrees Cent. nor above 110 degrees Cent. Care should be exercised to spread the sand over a large area in a thin layer in order to expel all the moisture in a given time. This will make it possible to add the proper amount of water and give the sand the desired moisture content.

15. After the sand has cooled, measure out the desired quantity of water, adding sufficient extra water (usually from one-fourth to one per cent) to allow for evaporation during mixing. Thus if it is desired to add 4 per cent water and

one-half per cent extra water is needed, one would add 47 cubic centimeters (since one cubic centimeter of water weighs 1 gram) to 1000 grams, and secure a total weight of 1047 grams.[4]

16. For the tempering operation, spread the sand on a smooth flat dry surface in a layer about 1-inch thick, sprinkle a small quantity of the required water evenly over the sand, and work the latter gradually. Again spread it into a thin layer and repeat the above operations, adding more water. Continue to do this until all of the water has been thoroughly distributed through the sand. There should be no dry lumps or other evidence of uneven tempering.

17. The sand should now be allowed to stand in order that the maximum temper may be developed. To secure this temper place the sand in a humidor or air tight receptacle, and allow it to stand for 24 hours. After this, the sample is ready to be tested, as below.

18. Take the entire sample of sand from the humidor. Pass this entire sample twice through a coarse riddle and return the sand as quickly as possible to the humidor or receptacle. From this take sample to be tested for permeability; also sample to be tested for moisture content, and for cohesiveness if desired.

Ascertaining Moisture Content

19. The moisture content is to be determined as follows: Dry 100 grams of tempered sand for one hour between 105 degrees and 110 degrees Cent. When dry reweigh. The loss of weight in grams is the moisture content expressed as percentage.

Ramming Of Specimen

20. Take a sufficient quantity (from 150 to 200 grams) of tempered sand to make a column 2 inches (5.08 centimeters) high, with a tolerance of 4 per cent. The sand should be carefully placed in the container E, and gently leveled off. Place pedestal

[4]Moisture content for all molding sand determinations and tests is to be expressed as the precentage of moisture in the *damp* sample of sand. It is not proper to calculate the amount of moisture, proportionate to the weight only of the dry sand.

and container with sand in position beneath rammer. Gently lower rammer-rod with head into container until they are supported by the sand. Raise rammer-head to the upper stop, and let fall. Repeat twice, making a total of 3 rams. Note whether the upper end of the rod is within the tolerance marks. If not, discard the sample and put in another lot of tempered sand of sufficient quantity to yield a column of the required height. This is usually accomplished on the second trial. Lift rammer-rod until disc at lower end of rod is free from the sand container, and take container off of pedestal.

Measurement Of Air Flow

21. Fill tank A with water to within 4¾ inches (12.2 centimeters) of the top. Before attaching sand container with specimen, open valve D, and raise bell B until mark "X" appears. Then close valve D. Attach sand container to rubber stopper H, moistening sides of stopper before applying, to prevent air leakage. Open valve D. Note scale on side of bell B, and as cup sinks, and zero mark on scale passes edge of tank A, start stop-watch. Read pressure in manometer tube as soon as the pressure reading becomes steady. The instant the "2000" mark on bell B reaches upper edge of tank A, the stop-watch should be stopped and time recorded. This represents the time required to force 2000 cubic centimeters of air through the sand. The time and pressure obtained as above, are to be used as described in paragraphs 22 to 24 inclusive.

Calculation of Permeability

22. The degree of permeability as determined by this test is found by employing a formula. By its use, permeability is ascertained as the volume of air per minute, per gram per square centimeter pressure, per unit volume in specimen.

23. Permeability equals the number of cubic centimeters of air forced through the sand specimen, multiplied by the height of the sand specimens in centimeters; and this product divided

by the product of the pressure in grams, the area of the sand specimen in square centimeters, and the time in minutes. Thus

$$Permeability = \frac{cm^3 \text{ of air } x \text{ cm height of specimen}}{\text{grams pressure } x \text{ cm}^2 \text{ area of specimen } x \text{ minutes}}$$

24. The method of conducting the permeability test herein described calls for 2000 cubic centimeters of air to be forced through the specimen; 5.08 centimeters (2 inches) to be the height of the specimen; and 20.268 square centimeters (3.1416 sq. in.) to be the area of the specimen. These fixed quantities are therefore substituted as constants in an equation as follows:

$$Permeability = \frac{2000 \times 5.08}{20.268 \times \text{grams pressure } x \text{ minutes}}$$

Reduced to its simplest terms this equation reads:

$$Permeability = \frac{501.2}{\text{grams pressure } x \text{ minutes}}$$

Rapid Method for Using the Permeability Apparatus

25. By making a slight change in the standard apparatus, which can be quickly readjusted for standardization purposes, greater rapidity of operation can be obtained at a slight sacrifice of accuracy.

26. This change consists only in inserting one of two standardized orifice-plates in the lower end of nipple G. These orifice-plates must be lined with some material which does not corrode or wear rapidly. Hard gold is recommended for this purpose.[5]

27. Two orifice-plates, the details of which are shown (K, Fig. 2) are made of brass. These plates are so designed as to be screwed into the lower end of the nipple G, which is threaded on the inner side and has the end faced square, so that the orifice-plate can fit snugly against it and make an air tight joint. Through the center of each orifice-plate a hole is drilled, counterbored at both ends, as shown in Fig. 2. The hole in each orifice-plate is filled with a hard

[5]The plugs through which the orifices are drilled are so small that it is not a serious item of expense to make them of gold. Jewelers have furnished these gold plugs for $5.00 per pair.

gold plug, through which plug another hole is drilled. The holes constituting the two orifices should be drilled exactly .5 millimeters (.0197 inch) and 1.5 millimeters (.0590 inch) respectively. For the last named hole, drill No. 53 may be used.

28. The orifices are standardized as follows: The smaller orifice-plate is screwed into its place in nipple G but the sand container is not attached to the apparatus. The weight is added to the top of the bell so as to give 10 centimeters pressure. Raise the bell B and allow it to descend, noting the time required for the cup to settle from the "O" to the "2000" mark. This gives the time required to pass 2000 cubic centimeters of air through the orifice, and should be 4.5 minutes. If the time required to accomplish this is greater than the above, the orifice is too small and should be carefully reamed out until it passes 2000 cubic centimeters of air in the proper time. If the time is less than 4.5 minutes the orifice must be compressed to a smaller size, and re-reamed until it is of the correct diameter.

29. The second orifice, with 1.5 millimeter opening is standardized in the same manner, except that it should be made to pass 2000 cubic centimeters of air in 0.5 minutes.

30. Both orifices should be calibrated to within 1 per cent. The smaller orifice is to be used with medium to fine grades of sand, and the larger one with medium to coarse grades.

31. The orifice plate which is adapted to the sand container is to be screwed into its place in nipple G. The sand container with the sample of rammed sand is placed in position. Turn three-way valve to "vent" and raise bell B. Turn valve to "On" and allow bell B to sink. Read pressure on manometer F, and close valve.

32. To test additional samples, proceed by placing them in position in the machine, turning valve to "On" each time long

enough to get a reading on the manometer. Bell B need not be raised again until it has sunk to rest on the bottom of the tank.

33. Knowing the pressure obtained as above, the permeability of the sand can be obtained from the table I given on page 721. The columns headed "Pressure" give the readings on the manometer ranging from 0 to 10 centimeters. The other columns give the permeability values for the two orifices corresponding to the pressures shown.

34. To obtain the permeability value of any sand from this table, note from it the pressure corresponding nearest to that indicated by the manometer. Then look on same line in column corresponding to orifice used and read the permeability value.

35. It is possible to make from the table a direct-read scale, which can be attached to the manometer, thus permitting the permeability value to be read without reference to the table.

PERMEABILITY TEST PRESSURES AND CORRESPONDING VALUES, AS OBTAINED WITH ORIFICE-PLATES

Pressure	Permeability: Small orifice .5 mm.	Permeability: Large orifice 1.5 mm.	Pressure	Permeability: Small orifice .5 mm.	Permeability: Large orifice 1.5 mm
.1	...	....	5.1	14.3	134
.2	...	....	5.2	13.8	128
.3	...	....	5.3	13.4	126
.4	273	2450	5.4	13.0	122
.5	217	2000	5.5	12.6	119
.6	176	1620	5.6	12.2	115
.7	154	1350	5.7	11.8	112
.8	133	1200	5.8	11.4	108
.9	117	1060	5.9	11.0	105
1.0	105	950	6.0	10.7	102
1.1	93	850	6.1	10.3	99
1.2	80	780	6.2	10.0	96
1.3	79	710	6.3	9.7	93
1.4	72	650	6.4	9.4	90
1.5	67	610	6.5	9.0	88
1.6	62	550	6.6	8.8	85
1.7	58	525	6.7	8.5	82
1.8	55	492	6.8	8.2	80
1.9	52	467	6.9	7.9	77
2.0	49	440	7.0	7.7	75
2.1	47	417	7.1	7.5	73
2.2	44	398	7.2	7.2	70
2.3	42	376	7.3	7.0	67
2.4	40	358	7.4	6.7	65
2.5	38	341	7.5	6.5	63
2.6	36	326	7.6	6.3	61
2.7	34	313	7.7	6.0	58
2.8	33	300	7.8	5.8	56
2.9	31	287	7.9	5.6	54
3.0	30	275	8.0	5.3	52
3.1	29	264	8.1	5.1	50
3.2	28	253	8.2	4.9	48
3.3	27	243	8.3	4.7	46
3.4	25.8	235	8.4	4.4	44
3.5	24.2	226	8.5	4.2	42
3.6	23.4	219	8.6	4.0	40
3.7	22.7	212	8.7	3.7	38
3.8	21.8	205	8.8	3.5	36
3.9	21.0	198	8.9	3.3	33.4
4.0	20.0	193	9.0	3.1	32.0
4.1	19.5	185	9.1	2.9	30.0
4.2	19.0	178	9.2	2.6	27.8
4.3	18.4	173	9.3	2.4	25.6
4.4	17.8	167	9.4	2.2	23.2
4.5	17.3	163	9.5	1.9	21.0
4.6	16.7	156	9.6	1.7	18.4
4.7	16.2	151	9.7	1.4	..
4.8	15.7	146	9.8	1.1	..
4.9	15.2	142	10.0	..	..
5.0	14.7	138	..	..	..

Table I

Fineness Test

(*Revised May* 1, 1924)

Revision of Fineness Test

The description of the fineness test which follows this explanation differs from the description of the test as originally announced at the Cleveland Convention of the American Foundrymen's Association. The changes are found in the dimensions and tolerances for sieves adopted by the U. S. Bureau of Standards. As is explained in a footnote in the description of the Fineness Test, the Bureau of Standards has recently revised its specifications for sieves, thus making it necessary for the joint committee to revise its method for determining fineness of molding sands. The joint committee has from the beginning desired to incorporate in its requirements for determining the fineness of molding sands, only those tolerances that are acceptable to the U. S. Bureau of Standards.

Procedure For Molding Sands Containing No Clay Or Bonding Substance

1. 100 grams of sand dried for at least 1 hour at a temperature which shall not be lower than 105 degrees Cent. nor higher than 110 degrees Cent. are transferred to the first of a series of sieves, U. S. Bureau of Standards Nos. 6, 12, 20, 40, 70, 100, 140, 200, and 270; and placed in a Ro-tap testing-sieve shaker, or other machine, the use of which may yield identical results. This machine is run for 30 minutes, and the amount of sand remaining on each sieve is weighed and expressed in percentage. The portion passing the No. 270 sieve is known as No. 270 minus.

Procedure for Molding Sands Containing Clay or Bonding Substance

2. 50 grams[1] of molding sand, dried for at least 1 hour at a temperature which shall not be lower than 105 degrees Cent. nor higher than 110 degrees Cent., are put into a 1-

[1]Since a 100-gram sample involves so many siphonings as to make the test prolonged, a 50-gram sample is more convenient to use.

quart milk bottle or preserving jar, smooth on the inside with no sharp shoulders in the neck, to permit the sand to be easily removed with a small stream of water. 475 cubic centimeters of water and 25 cubic centimeters of a standard solution of sodium hydroxide (made by dissolving 10 grams of sodium hydroxide in 1000 cubic centimeters of water) are added, and the bottle or jar is covered and securely sealed. In using a pre-

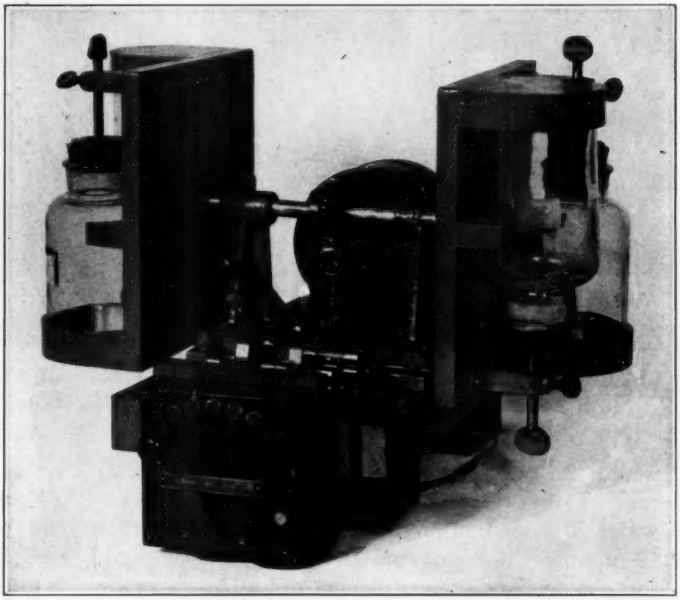

FIG. 1—SAND WASHING APPARATUS FOR USE IN CONNECTION WITH FINENESS TEST OF MOLDING SAND

tle or jar is covered and securely sealed. In using a preserving jar, instead of the usual rubber ring, a rubber disc is employed, which fits into the inside of the glass cover. The receptacle is then placed in a shaking machine, making about 60 revolutions per minute, in such a manner as to allow it to be up-ended at each revolution. At the end

of 1 hour the receptacle is removed, the cover is unsealed, and the sand adhering to the cover is washed into the receptacle. The receptacle is then filled with water, permitting the stream to stir up the contents, and allowed to stand for 10 minutes, when by means of a siphon extending to

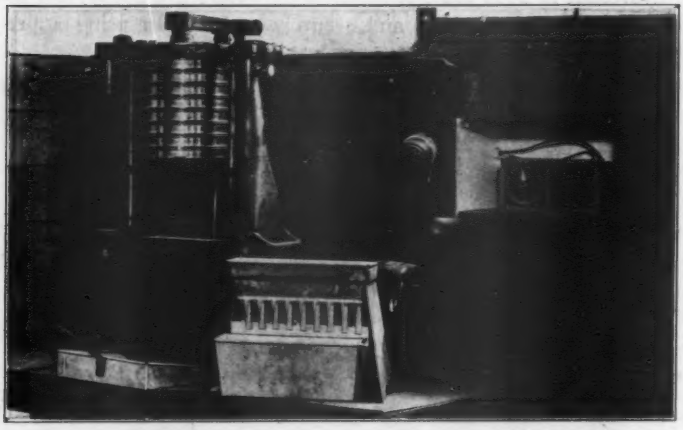

FIG. 2—ROTAP, SAND SCREENS AND TIME SWITCH SET UP AS USED IN CONNECTION WITH FINENESS TEST OF MOLDING SAND

within 2.5 centimeters (approximately 1 inch) of the bottom of the receptacle, the water is siphoned off. More water is added, filling the receptacle, and at the end of 10 minutes siphoned off. Water is added again, and at the end of 5 minutes siphoned off. The process of 5 minutes standing and siphoning is repeated until the water remains clear at the end of the 5-minute period. By this means the clay substance is separated from the grain, and may be collected in suitable containers and recovered by the addition of acid to neutralize the sodium hydroxide[2].

3. The grain remaining in the bottle or jar is washed on to a filter-paper, in a 9-centimeter Buchner's funnel, is

[2]For practically all known American molding sands this treatment is satisfactory. There are some foreign sands that are alkaline, and require an acid treatment, in which case tannic acid may be used.

drained by means of suction, then wet with alcohol, and transferred, together with the filter-paper, to a large glass, and dried for ½ hour at a temperature which shall not be lower than 105 degrees Cent. nor higher than 110 degrees Cent. The dried grain is weighed,[3], and the difference between its weight and that of the original 50-gram sample is ascertained to determine the clay substance.

4. The grain is then placed on the first of a series of sieves, U. S. Bureau of Standards Nos. 6, 12, 20, 40, 70, 100, 140, 200 and 270. These sieves are placed in a Rotap testing-sieve shaker, or other machine the use of which may yield identical results. This machine is run for 15 minutes, and the amount remaining on each sieve is weighed and expressed in percentage. The portion passing the No. 270 sieve is known as No. 270 minus.

5. The fineness test may be graphically expressed by ploting sieve numbers as abscissa against the grain remaining on each sieve, calculated as the per cent of 50 grams.

6. Series of Sieves, U. S. Bureau of Standards[4]

Sieve Number	Sieve Opening Millimeters	Sieve Opening Inches	Wire Diameter Millimeters	Wire Diameter Inches	Tolerance in Average Opening	Tolerance in Wire Diameter	Tolerance in Maximum Opening
6	3.36	.132	1.02	.040	±3%	—15 to +30%	10%
12	1.68	.0661	.69	.0272	±3%	—15 to +30%	10%
20	.84	.0331	.42	.0165	±5%	—15 to +30%	25%
40	.42	.0165	.25	.0098	±5%	—15 to +30%	25%
70	.210	.0083	.140	.0055	±6%	—15 to +35%	40%
100	.149	.0059	.102	.0040	±6%	—15 to +35%	40%
140	.105	.0041	.074	.0029	±8%	—15 to +35%	60%
200	.074	.0029	.053	.0021	±8%	—15 to +35%	60%
270	.053	.0021	.041	.0016	±8%	—15 to +35%	90%

[3]The filter-paper may be disposed of, after drying, by burning, as it lies on top of the sand sample.

[4]The Bureau of Standards notified the Joint Committee in April, 1924, of its revisions in standard specifications for sieves. The principal revisions permit considerably larger tolerances for wire diameter than had previously been called for. More latitude has been given in the revisions, for tolerances in average opening, than were previously prescribed. The revisions are accepted by the Joint Committee on Molding Sand Research, and are incorporated in the above table, which therefore does not correspond with the table in the description of the fineness test as previously published by the Joint Committee. It is most essential that the requirements of the U. S. Bureau of Standards as to size of opening be met, in the use of sieves for testing molding sand.

Series of Sieves Given for Fineness Test According to Method Announced At Cleveland Convention 1923

Sieve Number	Sieve opening millimeters	Sieve opening inches	Wire diameter millimeters	Wire diameter inches	Tolerance in average opening	Tolerance in wire diameter	Tolerance in maximum opening
6	3.36	.132	1.02	.040	1%	5%	10%
12	1.69	.0661	.69	.0272	2%	5%	10%
20	.84	.0331	.42	.0165	3%	5%	25%
40	.42	.0165	.25	.0098	3%	5%	25%
70	.210	.0083	.140	.0055	4%	10%	40%
100	.149	.0059	.102	.0040	4%	10%	40%
140	.105	.0041	.074	.0029	5%	15%	60%
200	.074	.0029	.053	.0021	5%	15%	60%
270	.053	.0021	.041	.0016	5%	15%	60%

The following foot note followed the above table of sieve series as reported at the Cleveland Convention.

[a]Sieve manufacturers have not unanimously agreed to make sieves conforming in every case as to wire diameter with the requirements of the U. S. Bureau of Standards. However, the sizes of openings prescribed by the Bureau are in accordance with those in sieves now being manufactured.

The Joint Committee on Molding Sand Research has not been able to determine if the slight existing differences as to wire diameter in sieves whose sizes of openings correspond, would influence the fineness tests recommended by the Joint Committee. Therefore, the said committee at this time feel justified in strongly urging that all sieves used in the fineness testing of molding sands conform with the requiremnts of the U. S. Bureau of Stanuarus as to size of opening, inasmuch as this factor is of vital importance in the comparison of fineness tests and in cases in dispute.

Dye Adsorption Test

Introduction

1. The application of the dye adsorption phenomenon to molding sand is solely for the purpose of ascertaining the nature of the clay substance present. Different sands possess widely different adsorption capacities, and this difference is due exclusively to the quantity of colloidal material present. The colloids in molding sands are mostly of an inorganic nature; hydrated aluminum silicate, hydrated iron oxide, hydrated silicic acid and other hydrated minerals. All of these constituents are of a gelatinous and sticky nature and they impart to the sand the property of bond. Strongly bonded molding sands commonly possess clay substance that is high in colloid content as measured by the dye adsorption test. The weaker bonded sands generally show a lower dye adsorption figure corresponding to the smaller quantity of colloids present in the clay substance of those sands.

Procedure

2. 25 grams of molding sand, dried for 1 hour at a temperature which shall not be lower than 105 degrees Cent. nor higher than 110 degrees Cent., are weighed into a 500 cubic centimeter wide-mouth bottle fitted with a glass stopper, and 300 cubic centimeters of distilled water, plus 5 cubic centimeters of 10 per cent ammonium hydrate, are added. The bottle is then stoppered, sealed with paraffin wax, and rotated in a suitable machine for 30 minutes (any machine such as that shown in the illustration of a shaker-machine, Fig. 1 page 55 of the fineness test, making approximately 60 revolutions per minute and up-ending the bottle with each revolution is satisfactory). At the end of this period 90 cubic centimeters of distilled water are added, plus 5 cubic centimeters of 10 per cent acetic acid. Crystal violet dye is then added in sufficient weight to allow for the adsorption by the colloidal matter and leave a slight excess. For molding sands of weak bond, 0.125 grams of dye is a good amount to start with; while the stronger sands require an addition of 0.150-0.300 grams or more of dye. After adding the crystal violet the bottle is sealed again

and rotated for another 30-minute period. If all the dye is taken up by the colloidal matter, more should be added, as it is necessary that an excess of dye be present over that required to satisfy the adsorption capacity of the colloids.

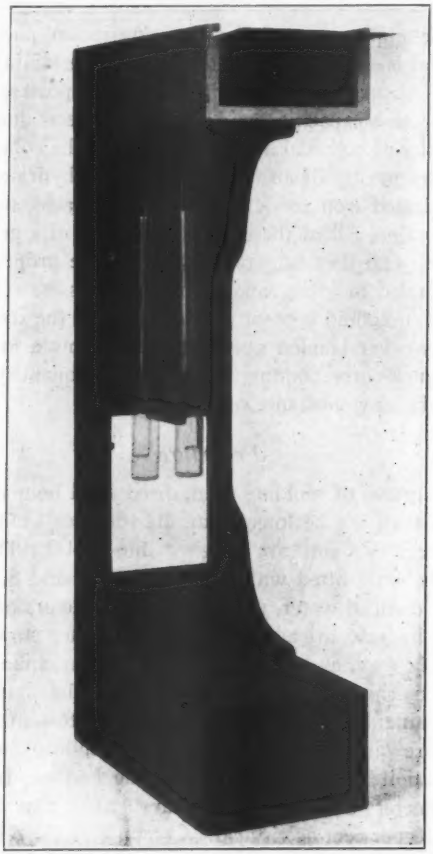

FIG. 1.—COLOR COMPARISON TUBE HOLDER WITH TUBES IN PLACE.

3. In order to determine the amount of dye adsorbed by the sand it becomes necessary to find the quantity unadsorbed or held

in solution. If the test is allowed to stand over night, suspended material settles out, leaving a clear solution of the dye, and the dye unadsorbed can be determined by color comparison. The standard color solution is made up by dissolving 0.500 grams of crystal violet in 500 cubic centimeters distilled water. Twenty-five cubic centimeters of the clear dye solution are taken from the test by a pipette and run into one of a pair of "carbon" compairson tubes, such as are used in steel analysis (as shown in the illustration of a colorimeter Fig. 1) diluted to 50 cubic centimeters and thoroughly mixed. Forty cubic centimeters or more of distilled water are added to the second comparison tube, and the standard dye solution added from a burette until the color matches that of the test in question, taking care that the final volume is the same in both tubes. If it required 2.5 cubic centimeters (0.0025 grams) in the standard tube to match the color in the test, then we have 0.0025 grams of dye unadsorbed in 25 cubic centimeters or 0.040 grams in 400 cubic centimeters. This figure is subtracted from the amount of dye added to the test, multiplied by 4, and the result expressed as milligrams of dye adsorbed per 100 grams of sand.

Notes

Electrolyte. The presence of ammonium acetate in the test is helpful in that its presence tends to bring about rapidly the subsidence of the fine particles which otherwise would remain in suspension. It has no serious effect on crystal violet. The addition of ammonium hydrate acts as a partial deflocculator and thereby breaks up the agglomerations of clay or other bonding substances.

Dye. Only the highest grade of crystal violet should be used. Impure dye gives low figures and is unstable. Standard dye solution should be kept in the dark, and a fresh quantity should be prepared frequently.

Used Sands. The dye adsorption test cannot be relied upon for all grades of used sands. Impurities present in some heap sands, as for example, seacoal, iron scale, organic binders, etc., seriously affect the adsorption results.

Dye Concentration. The final concentration of crystal violet should be not less than 0.024 grams, or more than 0.060 grams, in

400 cubic centimeter volume. A greater excess of dye gives high reading. After making a few tests it is a simple matter to judge the density of the clear dye solution, and it is essential that the proper concentration is obtained before the test settles overnight.

The Chemical Analysis of Molding Sand

1. The sample shall be ground to pass through a 100-mesh sieve, be dry to the touch, and be representative of the whole material under test. All determinations, except the determination of water at 105-110 degrees Cent. shall be made on the sample dried at said temperature and weighed out as follows; dry, cool and weigh the sample as below, quickly transfer the needed portion, restopper the bottle and weigh again. No further sample should be taken from an opened weighing bottle until the contents have been redried. Distilled water shall be used throughout and concentrated acids are meant unless otherwise specified. All analyses shall be corrected by blank runs on the reagents carried along with the analyses. For detailed information concerning the various analyses, the analyst should consult: .*The Analysis of Silicate and Carbonate Rocks,* by W. F. Hillebrand, United States Geological Survey Bulletin 700; *The Chemical Analysis of Rocks,* third Ed., by H. S. Washington, John Wiley and Sons; and a *Treatise on Quantitative Inorganic Analysis,* by J. W. Mellor, J. B. Lippincott Company.

Determination of Water at 105-110 *Degrees Cent.*

2. Carefully air-dry a portion of the sample and weigh 1 gram portions in a tared, wide, low-form, flat-bottomed weighing bottle. Heat uncovered in a ventilated drying oven at a temperature not below 105 degrees Cent. nor above 110 degrees Cent. for one hour. Lightly stopper and cool in a desiccator. Lift the stopper momentarily just before weighing, restopper, and weigh. The use of a similar weighing bottle as a counterpoise carried through all of the operations is a desirable procedure. Calculate the percentage loss and report as "H_2O at 105-110 degrees Cent." This determination is not necessary in the summation of results, but desirable for the study of different varieties of molding sands.

Determination of Total Volatile Matter
(Loss on Ignition)

3. Transfer 1 gram of the sample, dried at a temperature not below 105 degrees Cent. nor above 110 degrees Cent. to a tared platinum crucible with cover, warm gently under oxidizing conditions until moisture has been expelled, then at dull redness until carbonaceous matter has been destroyed, and finally with cover on and at approximately 1000 degrees Cent. to constant weight. Calculate the percentage loss and report as "Loss on Ignition." This determination represents water not driven off at 105-110 degrees Cent. carbon dioxide and carbonaceous matter and is subject to any oxidation changes. A true water determination above 105-110 degrees Cent. would require heating in a closed tube with absorption and weighing of the water.

Determination of Silica

4. Transfer 2 grams of the sample, dried at 105-110 degrees Cent. to a platinum crucible, mix intimately with 10 grams of sodium carbonate, cover, and heat carefully until the evolution of carbon dioxide occasioned by the reaction between silica and carbonate has ceased. Finally heat until the material is decomposed and the fusion is quiet. Cool, place the crucible cover in an evaporating dish, preferably of platinum to eliminate contamination, and, for the sake of celerity in evaporation, treat with a little dilute hydrochloric acid, scrub clean and remove. Cover the cooled melt with water and gently warm. Melts can usually be so loosened from crucibles with even sides. Transfer the loosened melt to the evaporating dish containing the faintly acid solution used to clean the cover and take care to avoid mechanical loss through effervescence. Wash out the crucible and remove any adhering matter by treatment with dilute 1:1 hydrochloric acid and scrubbing. Finally cover the evaporating dish and warm until the melt has been decomposed, hastening solution by breaking up resistant lumps with the flattened end of a glass rod. When effervescence has ceased, remove and wash the cover glass and evaporate the contents of the dish to dryness, breaking up crusts from time to time with a platinum or glass stirring rod kept in the dish. When thoroughly dry, cool and

drench the residue with hydrochloric acid and allow to stand for a few minutes. Add an equal volume of water, cover the dish and warm on the water bath for ten minutes. Filter on a paper of suitable size, wash thoroughly with hot dilute hydrochloric acid (5:95) and finally with hot water. Reserve the residue.

5. Evaporate the filtrate to dryness, thoroughly dehydrate as before, and again treat with acid and filter, but using as little acid as possible and allowing but a few minutes time for the digestion of the residue in acid. Filter the solution through a second and smaller paper, wash with a little cold dilute hydrochloric acid (1:99), and finally with a little hot water. No considerable washing of the small paper and silica recovery should be required. Reserve the filtrate and washings for the determination of iron and aluminum as below.

6. Transfer, wet or dry, and two papers containing the silica recoveries to a platinum crucible. Char carefully without allowing the paper to inflame, ignite until carbon has been destroyed, and finally with cover on at approximately 1200 degees Cent. to constant weight. Moisten the impure silica with a few drops of dilute sulphuric acid, carefully add sufficient hydrofluoric acid to decompose the silica, and slowly warm until all danger from effervescence is over. Finally evaporate to dryness, carefully ignite until sulphates are decomposed and then heat at approximately 1000 degrees Cent. Cool, weigh, subtract this weight from the weight of the impure silica, add the weight of any recovery obtained in the determination of iron and aluminum and calculate the percentage of silica.

Determination of Total Iron, Aluminum and Titanium Oxides

7. Fuse the nonvolatile residue from the silica determination with as little sodium carbonate as possible, dissolve the cooled melt in dilute hydrochloric acid and add the solution to the filtrate reserved from the silica determination.

8. Add a few drops of nitric acid or bromine water and boil the solution until all trace of chlorine or bromine is gone. Then add hydrochloric acid, if not already present, sufficient to

insure a total volume of 10 to 15 cubic centimeters of the acid. Add a few drops of methyl red solution, dilute to 200 to 250 cubic centimeters and heat the solution to boiling. Neutralize by the careful addition of dilute ammonia (1:1) (more dilute toward the end) until the color of the liquid just changes to a distinct yellow. Boil for one minute, allow to settle, filter, and wash the precipitate at once two or three times with hot 2 per cent ammonium chloride solution. Reserve the filtrate. Dissolve the precipitate on the paper in hot, dilute hydrochloric acid (1:1), catching the solution in the original beaker, and washing the paper thoroughly with hot water. Reserve the paper as it may contain some undissolved aluminum hydroxide. Boil the solution, add a little macerated filter paper and reprecipitate with ammonia as above. Transfer the precipitate as completely as possible to a new filter by means of hot 2 per cent ammonium chloride solution. Finally remove any adhering hydroxide from the inside of the beaker by scrubbing with the reserved paper which is to be added and burned with the precipitate. Add the filtrate to the reserved filtrate and save for the determination of calcium as below.

9. Transfer the precipitate to a weighed platinum crucible and heat very gently until all danger of mechanical loss has passed, then at a higher temperature and under oxidizing conditions until carbon has been destroyed, and finally for 10 minutes with crucible covered over the blast lamp or its equivalent. Cool and weigh with the crucible tightly covered, as Al_2O_3 + Fe_2O_3 + TiO_2 + SiO_2. Reserve the residue for the recovery of silica and determination of total ferric oxide and calculate the percentage of combined oxides.

Recovery of Silica and Determination of Total Ferric Oxide

(a) Recovery of Silica

10. Add 3 to 4 grams of potassium or, preferably, sodium pyrosulphate to the combined oxides, snugly cover the crucible, and carefully heat until the salt is melted and in quiet fusion. Continue the heating at a very dull red until the oxides are in solution. This fusion can not be hurried and must be performed at the lowest temperature which will prevent the forma-

tion of a crust on the melt. Take up the cooled melt with so much dilute sulphuric acid that there shall be not less than 5 cubic centimeters of absolutely acid and enough water to effect solution.

11. Evaporate the solution and eventually heat until sulphuric acid fumes come off copiously. After cooling, dilute to approximately 100 cubic centimeters stir until salts are dissolved and make sure than any small residue is silica and not unfused oxide, as shown by a light flocculent suspension as against a fine powder. Filter without delay, wash with hot water until free from soluble salts and reserve the filtrate. Ignite the residue, weigh, correct with hydrofluoric acid treatment and add the weight of silica recovered to that previously found and deduct from the gross weight of the combined oxides.

12. In case the non-volatile residue is appreciable in amount, it must be recovered and added to the reserved filtrate by fusion with pyrosulphate and solution in sulphuric acid.

(*b*) *Determination of Total Ferric Oxide*

13. Pass the hot reserved filtrate, preferably of 100 to 200 cubic centimeters volume and containing 5 per cent by volume of sulphuric acid, through a Jones reductor using the customary precautions, and *quickly* titrate the reduced solution with an approximately 0.03 *N* potassium permanganate solution which has been standardized against the Bureau of Standards standard sodium oxalate. Reserve the titrate solution for the determination of titania, and after subtracting the permanganate required in a blank run, calculate the percentage of Fe_2O_3. This value will be too high if titanium or vanadium are present. The latter need not be feared in this class of material; the effect of the former is overcome by subtracting the percentage of titania found below, (The TiO_2 titre of a permanganate solution is the same as the Fe_2O_3 titre). If a determination of *ferrous* oxide is made, the percentage found must be calculated to Fe_2O_3 and substracted from the above value in order to get the percentage of *ferric* oxide in the sand.

14. The determination of iron under the above conditions is not strictly accurate on account of the instability of the re-

duced titanium solution; the error is slight if the amount of titania is small.

Determination of Titania

15. Evaporate the titrated solution to a volume of approximately 75 cubic centimeters, cool, transfer to a 100 cubic centimeters Nessler comparison tube, add 5 cubic centimeters of 3 per cent hydrogen peroxide and dilute to the 100-cubic centimeter mark. In another tube mix the same amount of fusion salt, iron as ferric sulphate, and acid as are in the unknown, dilute to approximately 95 cubic centimeters and then add standard titanium sulphate solution until the colors match. Calculate the percentage of TiO_2 and subtract this value from the calculated percentage of FeO_3 obtained above.

Determination of Alumina

16. Subtract from the weight of $Al_2O_3 + Fe_2O_3 + TiO_2 + SiO_2$, (a) the weight of silica recovered from it, (b) the calculated weight of Fe_2O_3 obtained, and (c) the calculated weight of TiO_2. Regard the remainder as Al_2O_3 and calculate its percentage.

Determination of Lime

(*a*) *Gravimetric Method*

17. Add a few drops of ammonia to the combined filtrates from the ammonia precipitation and bring the solution to boiling. To the boiling solution add 10 cubic centimeters of a saturated solution of ammonium oxalate and continue the boiling until the precipitated calcium oxalate assumes a granular form. Allow to settle for at least one hour, filter, and wash with boiling water, using no more than necessary on account of the solubility of the oxalate. Reserve the filtrate and washing for the determination of magnesium. With the small amounts of calcium, magnesium and aluminum involved, it is hardly necessary to dissolve the precipitate and attempt to recover the latter two. Ignite the precipate to lime in a weighted platinum crucible with cover, at first uncovered until the carbon has been destroyed and then well covered to constant weight. Calculate the percentage of CaO.

(*b*) *Volumetric Method*

18. Transfer the paper and precipitate obtained as in the gravimetric method to the well washed beaker in which the precipitation was made, spreading the paper out against the upper portion of the beaker. Wash the precipitates from the paper with a jet of hot water, fold the paper and leave it adhering to the upper portion of the beaker. Add to the contents of the beaker 50 cubic centimeters of dilute sulphuric acid (1:10), dilute to a volume of 250 cubic centimeters with hot water, and heat to a temperature of 80 degrees to 90 degrees Cent. Titrate with a standard approximately 0.03 *N* permanganate solution until the pink end point is obtained. Now drop the folded filter paper (which has been adhering to the side of the beaker) into the liquid, stir, and continue the titration until the pink color is again obtained. A Gooch crucible may be used instead of filter paper. From the total quantity of standard permanganate solution used calculate the percentage of CaO.

Determination of Magnesia

19. Acidify the filtrate from the calcium precipitate with hydrochloric acid, and concentrate on the water bath to about 200 cubic centimeters. Add 10 cubic centimeters of a saturated solution of microcosmic salt and then ammonia dropwise until a crystalline precipitate begins to form or the solution is alkaline. Finally add 10 cubic centimeters in excess and allow the solution to stand at room temperature for from 12 to 48 hours. Filter, rinse the beaker with a little 5 per cent by volume ammonia, wash the precipitate slightly and discard the filtrate.

20. Dissolve the precipitate adhering to the beaker and on the paper in hot dilute hydrochloric acid, dilute to 100 cubic centimeters add 1 cubic centimeters of a saturated solution of microcosmic salt and ammonia dropwise as before and finally in 5 to 10 cubic centimeters excess. Allow to stand for 6 to 24 hours, filter on paper and wash with dilute 5 per cent by volume ammonia. Heat the wet or dry precipitate carefully (preferably in a muffle) until the paper chars without flaming, destroy the carbon under oxidizing conditions and at the lowest possible temperature, and finally ignite at approximately 1000 degrees

Cent. to constant weight. Calculate the percentage of MgO from the weight of $Mg_2P_2O_7$ obtained.

Determination of Carbon Dioxide

21. Determine the carbon dioxide on a 10-gram sample, dried at 105 degrees Cent. according to the method given in the United States Geological Survey Bulletin No. 700, pages 217-8.

22. In brief, the method is as follows: Boil the weighed sample with dilute hydrochloric acid in a small Erlenmeyer flask attached to an upwardly inclined condenser, whence, after passing through a drying system—calcium chloride, anhydrous copper sulphate to retain hydrogen sulphide from decomposable sulphides and any hydrochloric acid that may pass over, then calcium chloride again— the carbon dioxide is caught by weighed absorption tubes filled with soda lime or with ascarite, and calcium chloride. The drying system should employ successively calcium chloride, anhydrous copper sulphate, and calcium chloride again. The function of the anhydrous copper sulphate is to retain hydrogen sulphide from decomposable sulphides and any hydrochloric acid that may pass over. Of course, arrangement is made for a current of air free from carbon dioxide with which to sweep out the apparatus before and after the determination and for a slow current during its continuance. Calculate the percentage of carbon dioxide.

Determination of Potassium and Sodium Oxides

23. Grind a little more than 1 gram of the sand in a small agate mortar with 0.5 gram of ammonium chloride and thoroughly mix by grinding with the pestle. Next weigh out about 5 grams calcium carbonate and use small portions as directed below. First transfer sufficient carbonate to form a thin layer on the bottom of an unweighed, deep form, platinum crucible, next thoroughly mix about 3 grams of the carbonate with the already mixed sand and ammonium chloride, carefully transfer the mixture of the three to the platinum crucible and finally scrub the mortar and pestle with the remaining carbonate and pour on the mix as a cover.

24. Snugly cover the crucible and heat over a low flame for ten minutes or until no more vapors are given off. Continue the heating with only the lower third of the crucible heated to dull red (best set in an asbestos shield) for three-quarters of an hour and allow to cool.

25. When cold, cover the sinter in the crucible with water, allow to slake and transfer the contents to a platinum dish. Dilute to 50 cubic centimeters, rub up the mass with an agate pestle, rinse off the pestle and boil the solution for five minutes. Decant through a 9 centimeter filter into a 600-cubic centimeter beaker. Repeat the rubbing and extraction treatment at least three times.

26. Treat the filtrate with a little ammonia, bring to boiling, add about 2 grams of ammonium carbonate dissolved in 25 cubic centimeters of water, and continue the boiling for a minute or so. Allow the bulky precipitate to settle, filter into a 500-cubic centimeter dish of porcelain or platinum, wash the residue with hot water and evaporate the filtrate to dryness over a water bath.

27. Place the basin, covered with a glass, on a square of gauze over a low flame, heat very carefully until all danger of decrepitation is passed and then remove the cover and continue the heating until all ammonium salts have been expelled Heat at as low a temperature as possible to avoid loss of alkali chlorides by volatilization. Cool the dish, add enough water to dissolve the chlorides, then a drop of barium chloride solution (or more if appreciable amounts of sulphates are indicated) and finally a few drops of ammonium carbonate solution to precipitate the excess of barium and the last traces of lime. Make sure that all soluble salts are in solution and again evaporate almost to dryness. Treat with 5 cubic centimeter of water and filter through a 5.5 centimeter filter placed in a 3.5 centimeter funnel, into a previously weighed 35 cubic-centimeter crucible with cover. Wash the paper and residue with 3 to 4 cubic centimeter portions of hot water, add one drop of hydrochloric acid to the filtrate, and evaporate the solution to *complete* dryness on the water bath. When dry, cover, place on

a triangle and very cautiously heat until danger of decrepitation is past. When vapors of ammonium chloride rise, raise the heat gently until all are driven off; finally raise the cover and heat it as well as the crucible gently till free from ammonium chloride. The heating of the cover should be done below red heat and the heating of the crucible should be gaged so that the chlorides suffer no more than incipient fusion.

28. Cool the crucible and contents in a desiccator and weigh as NaCl + KCl. Test the mixed chlorides for purity by dissolving them in 5 to 10 cubic centimeters of water. If the solution is clear, proceed as below; if the solution is turbid, filter and wash as before and again evaporate to dryness and weigh.

(a) *Determination of Potassium Oxide*

29. Treat the solution of the mixed chlorides with sufficient chloroplatinic acid to combine with both sodium and potassium. (If the solution of chloroplatinic acid contains 0.05 grams of platinum per cubic centimeters this may be assured by adding as many cubic centimeters as 34 times the weight of the combined chlorides.) Place on the water-bath, evaporate until the solution is syrupy, cool and then half fill the crucible with alcohol of 0.86 specific gravity (approximately 80 per cent by volume). Allow to stand with occasional gentle stirring until the sodium salt has dissolved and the residue is golden-yellow. Filter through a weighed Gooch crucible, wash with the 80 per cent alcohol, dry at 130 degrees Cent. and weigh as K_2PtCl_6.

30. Subtract the weight obtained in the blank, multiply the corrected weight by 0.1938 to get the weight of K_2O and calculate the percentage of K_2O.

(b) *Determination of Sodium Oxide*

31. Multiply the weight of K_2PtCl_6 by 0.307 to reduce it to KCl, subtract from the weight of the mixed chlorides and multiply the weight of sodium chloride so found by 0.5308 to reduce it to Na_2O. Correct this weight as indicated by the blank and calculate the percentage of Na_2O.

Determination of Ferrous Oxide

32. This determination is attended by several difficulties. Satisfactory results are impossible in the presence of carbona-

ceous matter. If the material is coarse and difficulty soluble, any grinding must be most carefully done to avoid oxidation. The method to be described below is applicable in the absence of organic matter and does not require special apparatus.

Method

33. Test a small portion of the sand by gently boiling for 20 minutes with hydrofluoric acid in a covered platinum crucible. If the above test shows that the sample leaves but little residue, take 0.5 to 1 gram of the sample, dried at 105 degrees Cent. and place it directly in a platinum crucible of 80 to 100 cubic centimeters capacity. In case the sample is not easily decomposed, transfer the weighed portion to an agate mortar and grind under absolute alcohol only long enough to yield a powder that will leave little or no residue on solution. Allow the alcohol to evaporate spontaneously and when the last trace has disappeared, transfer the powder to the platinum crucible and rinse the mortar and pestle with a jet of hot water.

34. In either procedure cover the powder with a little air-free water, and add 10 cubic centimeters of dilute sulphuric acid (1:3) carefully and with cover on in case effervescence is noted. Add air-free hot water until the crucible is half full and place the covered crucible on a triangle well down over a lamp turned low and protected from drafts. Rapidly displace the air in the crucible by a stream of carbon dioxide directed beneath the lid raised on one side. Before allowing the liquid to boil, discontinue the gas current and cover the crucible with the well-fitting lid. Gently boil, draw the lid a little to one side, quickly add 10 cubic centimeters of hydrofluoric acid, replace the lid, raise the temperature cautiously until steam comes off, and then lower until there is steady ebullition without danger of loss. Steam should issue continually for 20 minutes or as many minutes as may be deemed necessary or allowable. Transfer the crucible, still covered, to the titration vessel, which may be of glass (containing a cold saturated solution of boric acid in freshly boiled water with an excess of the solid acid and 5 cubic centimeters of sulphuric acid) and which is already

under the burette. Finally, titrate rapidly with a standard approximately 0.03 *N* permanganate solution until a first pink blush appears throughout the whole liquid.

35. If an unattacked residue shows after titrating, allow it to settle completely, decant off the top liquid, wash once by decantation, and transfer to an agate mortar by the aid of a jet of water. Allow to settle, decant off most of the water, grind under the water that remains and wash back again into the large crucible. Repeat the treatment with hydrofluoric and sulphuric acids as before, in smaller amounts and for a shorter time, titrate, and if necessary repeat the operation a third time. Calculate the percentage of FeO from the total amount of permanganate required.

Method of Sampling Sand as Shipped or Delivered

Time of Sampling

1. Collect the sample when the sand is being loaded into or unloaded from railroad cars, ships, barges, or wagons, or is being discharged from supply bins, industrial railway cars, grab buckets, or sand conveyors. In case the sand is crushed, or mixed by mechanical means, at the place of sampling, the sample should be collected if possible, after the sand has passed through the machine. Do not collect samples entirely from the surface of sand in piles or bins, or in cars, ships, or barges, as samples so collected are generally unreliable. A reliable and representative gross sample can be collected only by taking portions of sand from different parts of the mass, and such opportunity is afforded only when the sand is being transferred from one carrier to another—bank cars to railroad car, railroad car to barge, or wagon to bin, etc.

Collection of Gross Sample

2. Use a shovel for taking equal portions or increments to make up the gross sample, each portion or increment weighing about 10 pounds.

3. Collect the increments regularly and systematically, so that the entire quantity of sand sampled will be represented proportionately in the gross sample, and collect them at such intervals that the gross sample will be of the required size. The gross sample should contain the same proportion of lump sand, fine sand, and impurities as the sand sampled. When sand is extremely lumpy, making difficult the collection of representative increments by shovel, break a quantity of the lumps and collect portions, as required, from the broken lumps.

Size of Gross Sample

4. The gross sample must not be less than 500 pounds. Whether the quantity of sand consists of 1 ton, 500 tons, or more, the need of the gross sample being of the size stated is the same.

Quantity Represented by a Gross Sample

5. The number of gross samples that should be collected must vary for each consignment or shipment, and each case must be considered individually. For example, a shipment of 1000 tons, of 20 railroad cars of 50 tons each, may be represented by one gross sample of approximately 500 pounds, if properly collected; but in case sand from several pits enters the shipment and a separate gross sample from, say four cars to represent the sand produced by one bank is desired, or if for some other reason a sample is desired from four of the cars, then to represent the sand in the four cars a gross sample of 800 pounds should be collected by taking approximately 200 pounds from each car. If, for example, another sample for eight of the cars is required, then approximately 100 pounds should be taken from each car. The sampler will, presumably, be instructed as the number of gross samples desired, or the number of cars, or the sand each sample is to represent.

Storage of Gross Sample

6. As the shovelfuls or increments to make up a gross sample are taken, deposit them on a clean, tight and smooth floor or place them in clean barrels, boxes, or other receptacles. Protect the sample from rain, snow, wind, and beating sun. Do not let cinders chippings from floor, or any other foreign matter get into the sample. Inspect boxes, barrels, buckets, or other receptacles each time before using, to insure that they are clean.

Wagonload Sampling

7. Collect shovelfuls of sand from each wagon, or every second or third wagon, as the sand is being loaded into or unloaded from the wagon, the number of shovelfuls and the number of wagonloads sampled being dependent on the number of loads that the gross sample is to represent. If the sand is unloaded by shovel, take shovelfuls from different parts of the wagon or wagons; but do not take all shovelfuls from similar points, as from the surface or the ends of loads or from the very last sand remaining in the wagons. If dump wagons are used, take shovelfuls as the sand flows from the wagon; ob-

serving care, however not to take shovelfuls from the very first or last sand running.

Carload Sampling

8. Collect the number of shovelfuls or increments of sand required to make up the gross sample from different points in the car or cars, from top to bottom and from end to end, while the sand is being loaded or unloaded.

9. In sampling a shipment of sand at the bank, take the shovelfuls or increments systematically and regularly as the sand is loaded into the railroad cars, so that the gross sample will represent the entire quantity sampled. The frequency of collecting the increments will depend on the number of cars of sand to be represented by the gross sample. If only one railroad car is to be sampled collect from each unit dumped the number of shovelfuls required to obtain a gross sample of the required size. In case the car is filled by conveyor or chute increments shall be taken at intervals in that proportion which the total number of increments bears to the total loading time. If two or more cars of sand are to be represented by one sample, the gross sample should be collected by taking a shovelful of the sand dumped from each bank car or from every second, third, or fourth, etc., unit in order to have a gross sample of proper size, so that representative portions of sand will be taken in equal quantities from each car. In case the railroad cars differ in size the quantities taken from each car should be in proportion to the capacities of the cars. When sand is dumped from units into railroad cars, the lumps usually roll to the bottom, hence shovelfuls should not be collected entirely from the bottom of the car, but should be taken systematically over the surface of the sand.

10. In sampling sand being unloaded by shovel from cars, the shovelfuls to make up the gross sample should be taken at regular intervals. Workmen unloading sand usually begin by shoveling the sand out to the bottom so as to facilitate shoveling from the floor. As a result the load is exposed from top to bottom and an excellent opportunity is afforded for taking shovelfuls for the sample from different places in the face ex-

posed as unloading progresses, and it is easy to obtain a final sample composed of shovelfuls from all parts of the load, from top to bottom and from end to end.

11. In sampling sand from dump cars, shovelfuls may be taken from the stream of sand being discharged, observing care not to collect portions of the first or last sand spilling from the car. Because of the suddenness with which sand may drop out of a railroad car and because of the momentum of the rapidly falling mass, the collection of a satisfactory sample by attempting to catch shovelfuls may be impossible. In such event it may be necessary to collect shovelfuls of sand that has overflowed on the pier or the trestle deck or the sides of pockets. If beams 10 to 12 inches wide span the pockets immediately underneath the car a fairly satisfactory sample can often be collected in shovelfuls from the sand lodging on the beams.

Ship or Barge Sampling

12. In sampling a ship or barge, as in sampling a car, portions of sand should be taken in equal quantities and at frequent and regular intervals while the sand is being loaded or unloaded, so as to represent proportionate parts of the whole consignment. If the sand is unloaded by grab buckets, or into barrows or sand-conveying equipment, shovelfuls usually can be advantageously collected at regular intervals from the buckets, barrows or equipment.

Preparation of Gross Sample: Crushing

13. After the gross sample has been collected lumps must be broken up, the sand must be systematically mixed, and reduced to convenient size for transmittal to the laboratory. The breaking of lumps may be done with a hardwood tamper. If a suitable tamper is not available, a satisfactory tamper can be made from a piece of 6 by 6 inch timber, 12 to 15 inches long, by boring a suitable hole in one end and inserting a handle about 3 feet long and 1½ to 2 inches in diameter. The handle should fit the hole snugly. By splitting the end to be inserted and loosely placing a wood wedge therein the handle will be firmly held in place when it is driven home.

14. Break up the lumps on a smooth, clean, sheet-iron plate of suitable dimensions or on a solid floor. If a suitab'e plate or floor is not available, the work may be done on a heavy canvas. In preparing the sample, take care that no pieces fly out of it, and that no cinders, chipping from the floor, or any other foreign substances get into it. Prepare samples of the weight indicated in the accompanying table so that no lumps of sand will be greater in any dimension, as judged by the eye, than specified for the sample before division into two approximately equal parts as follows:

Weight in Pounds of Sample	Largest sizes of lumps allowable in samples before division. Inches
800	½
400	⅜
200	¼

15. The method of reducing by hand the quantity of sand in a gross sample must be carried out as prescribed below, even though the coarseness of the sand be less than is specified in the table .

16. The progressive reduction in the weight of the sample to the quantities indicated in the table must be done by the following methods, which are shown in the accompanying illustration.

Halving

17. The alternate-shovel method of reducing the gross sample is to be repeated until the sample is reduced to approximately 125 pounds. Before each reduction in quantity the sample must be crushed to the fineness prescribed in the table.

18. The crushed sand must be shoveled into a conical pile (Figs. 2 and 7) by depositing each shovelful of sand on top of the preceding one, and then formed into a long pile in the following manner:

19. The sampler takes a shovelful of sand from the conical pile and spreads it out in a straight line (Figs. 3A, and 8A) having a width equal to width of the shovel and a length of 4

to 6 feet. His next shovelful is spread directly over the top of the first shovelful, but in the opposite direction, and so on back and forth, the pile being occasionally flattened until all the sand has been formed into one long pile (Figs. 3B, and 8B).

20. Half of the pile thus formed must be discharged in the following manner:

21. Beginning on one side of the pile, at either end, and shoveling from the bottom, the sampler takes one shovelful (shovelful No. 1 Figs. 4 and 9) and sets it aside; advancing along the side of the pile a distance equal to the width of the shovel, he takes a second shovelful (shovelful No. 2 Figs. 4 and 9) and discards it; again advancing in the same direction one shovel width he takes a third shovelful (shovelful No. 3 Figs. 4 and 9) and adds it to the first. Shovelful No. 4 (Figs. 4 and 9) is to be taken in a like manner and discarded, the fifth shovelful (No. 5, Figs. 4 and 9) retained, and so on, the sampler advancing always in the same direction around the pile, so that its size will be reduced gradually and uniformly. When the pile is removed about half of the original quantity of sand should be contained in the new pile formed by the retained shovelfuls (Figs. 5 A, and 10 A, show the retained halves, and 5 B, and 10 B, the rejected halves).

Quartering

22. After the gross sample has been reduced by the above method to approximately 200 pounds, further reduction in quantity must be by the quartering method. Before each quartering the sample must be crushed to the fineness prescribed in the table.

23. Quantities of 100 to 200 pounds must be thoroughly mixed by coning and reconing (Figs. 12 and 13); quantities less than 100 pounds must be placed on a suitable cloth, measuring about 6 by 8 feet, thoroughly mixed by raising first one end of the cloth and then the other (Figs. 18 and 24), so as to roll the sand back and forth, and then formed into a conical pile by gathering together the four corners of the cloth (Figs. 19, and 25). The quartering of the conical pile must be done as follows:

24. The cone is flattened by pressing its apex vertically down with a shovel or board, so that when the pile is quartered each quarter will contain the material originally in it. The flattened mass, which must be of uniform thickness and diameter, is then marked into quarters (Figs. 14, 20 and 26) by two lines that intersect at right angles directly under a point corresponding to the apex of the original cone. The diagonally opposite quarters (*B, B* in Figs. 16 and 22) must then be shoveled away and discarded and the space that they occupied brushed clean. The sand remaining must be successively mixed, coned and quartered until opposite quarters shall equal not less than 12½ pounds of not greater than 4-mesh, size. Each of the 12½-pound quantities must be thoroughly mixed and placed in a container suitable for transportation to the laboratory.

Discussion—Report of Sub-Committee on Molding Sand Tests

Mr. Newhouse.—I would like to ask how long it would take to make tests such as these.

H. B. Hanley.—Mr. Newhouse, it must be considered from two angles. If you are making the tests on the sand heap right from the shop, you can put them through very rapidly; several samples could be handled in a day; if you were examining, however, a variety of new sands, you would lose considerably more time by finding out in accordance with the directions the best water contents to bring out the best permeability and the best water contents to bring out the best bonding or cohesiveness strength, so that the new sands take quite a little while. You would not get very far in a day with the examination of a new sand, but on plant control work, you could easily handle several samples in a day.

Mr. Newhouse.—I have special reference to plant control, because sometimes your sand may be running wrong and it is a question how long it would take before you could straighten things out; that is the reason I asked the question.

Chairman R. A. Bull.—Is Mr. Doty present? Mr. Doty has had a great deal to do in the development of this particular cohesiveness test and has made a great many of them. He can perhaps give you a very clear idea of the average amount of time necessary for that test. Mr. Saeger can give you similar information regarding the permeability test.

R. J. Doty.—It would be a little hard for me to describe the cohesiveness test alone, due to the fact that we run a lot of them simultaneously, but three hours from the time we start to investigate a sample sand, we have the answers to all three of these tests. That does not mean that the operator is busy with those three tests for three

hours. Part of that time he is doing other work, but the answer is available in three hours from the time he starts on sand in daily use in the foundry.

N. K. B. Patch—Are there no tests for the refractory value of the sand?

Chairman R. A. Bull.—Not as yet, Mr. Patch. The committee recognizes keenly the importance of such a test. It has some appreciation, too, of the difficulties to be encountered in the development of a satisfactory test. If any foundryman this year has what he might consider a good hunch as to how that test ought to be attacked in each of several phases, the committee would greatly appreciate the transmission of that information to itself. It hopes by the next convention of the association to present something of value on that subject.

R. S. McPherran.—We often find little pieces of gravel the size of the end of your thumb in this sand as received Are these left in until after the sieve test, or are they removed, and if removed to what extent are they taken out of the sample?

H. B. Hanley.—Now to answer that question, I might say that the committee has not considered whether it is right and proper to remove those pebbles before carrying out the details of the fineness test, but from the personal standpoint I would say that we all realize that those pebbles are not a part of the grade of the sand and they do not enter into the mold, especially in the case of fine sand. I do not know what the disposition of many operators would be on the separation, but I think all the members of our subcommittee would very gladly remove any excess sized particles or pebbles before carrying out a sieve test, using discretion about the different grades of sand being tested. For instance, on the gravels, a sand like a Millville gravel, we would probably remove anything around a half inch; we would take anything that went through a quarter inch riddle, but that is a matter of personal judgment. On the fine sands of the Albany type, we would not naturally take a pebble or many pebbles of a quarter of an inch, but if

they were there in very small percentages, we would just remove them mechanically in the weighing out or handling of the sand for the test.

Chairman R. A. Bull.—Mr. McPherran, I think there might be some difference of opinion in different foundry operations as to the advisability of removing those pieces of which you speak; while in the great majority of cases it would be advisable for the testing operator to quickly remove, or in some appropriate manner, remove those large pebbles, there are some phases of foundry work of which I happen to have some knowledge, where they are considered desirable by the foundryman, so it would probably be an optional matter on the part of the individual.

R. F. Harrington.—On that point right there, it occurs to me that the basis of whether or not one should take out those pebbles would be whether or not the sand would go through a number four riddle before it went into the foundry. If you were using a number four riddle to put your raw sand in, then if these remain on a number four riddle, they would have no effect at all. If you want to know what the effect of the sand is as it enters the mold, you would have no occasion to consider the pebbles because they would remain on the number four riddle. If, on the other hand, you wanted to arrive at the percentage of loss due to the pebbles, you would get at it from what remained on the number four riddle.

A Member.—I would like to ask if the committee has considered the rational analysis of sand in their work and whether they consider it of any practical value?

H. B. Hanley.—We have made quite a careful study of the rational analysis as applied to molding sands; we do not feel that we have completed our investigations, but with the kind co-operation of the bureau of standards, we have been led to believe from an investigation that they carried out for us, that there is very little merit left in the rational analysis as applied to molding sands.

John Petty.—If I understand it, all these series of tests will be carried out in a uniform manner; how would all this apply to hand-rammed molds?

Chairman Bull.—In the first place, you want to ram as uniformly as you can, don't you? If you do not ram your sample uniformly, you cannot get an index to what that mold will do, if it is not rammed in a theoretically correct manner.

John Petty.—How would these methods of tests control a hand-rammed mold?

Chairman R. A. Bull.—They would not; they would still give you an indication of what the sand would do if it were correctly tempered, correctly sampled and uniformly rammed; then you would have to apply your own experience to whatever differential you think would be proper, comparing the uniformity of ramming of that specimen with the uniformity you are getting on your foundry floor.

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